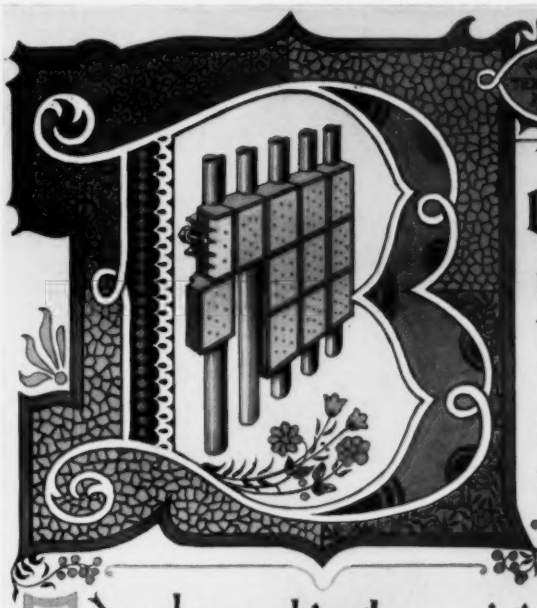

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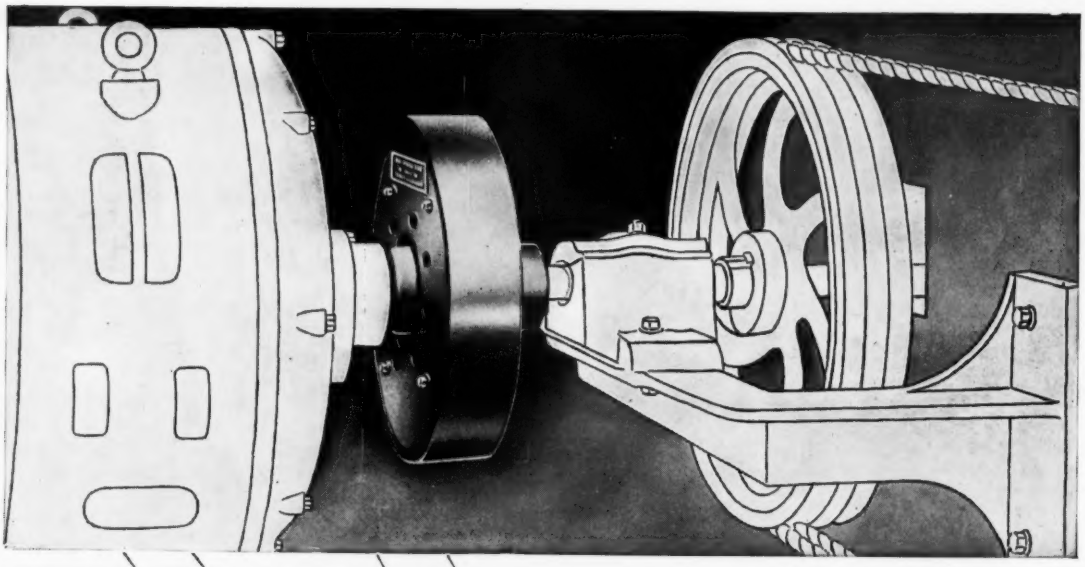

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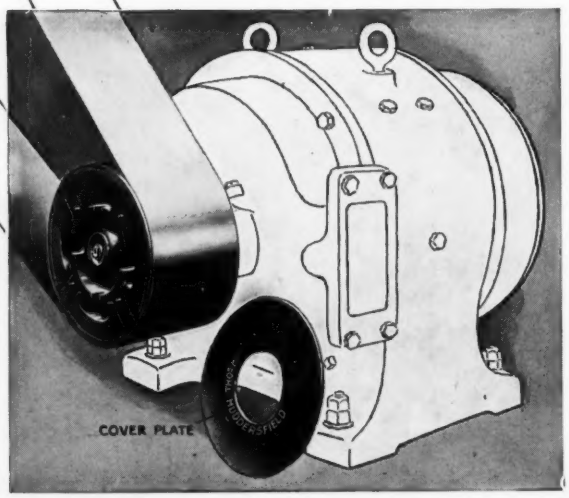

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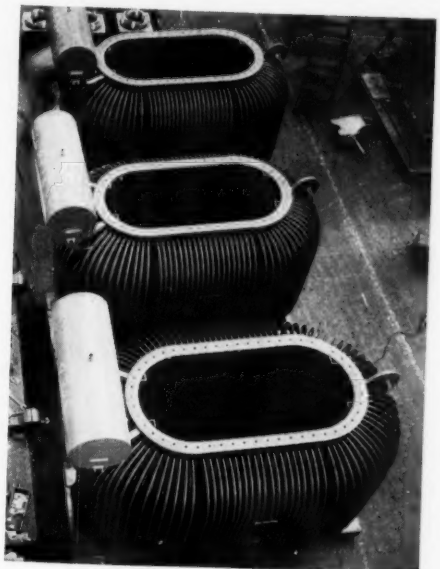

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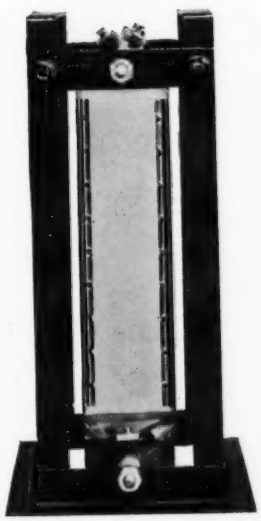

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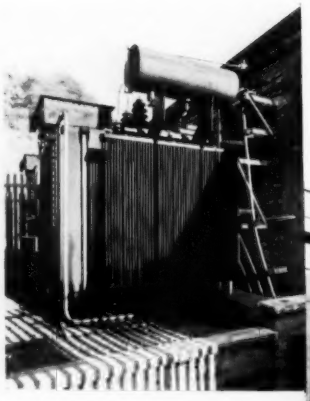

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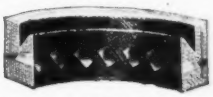

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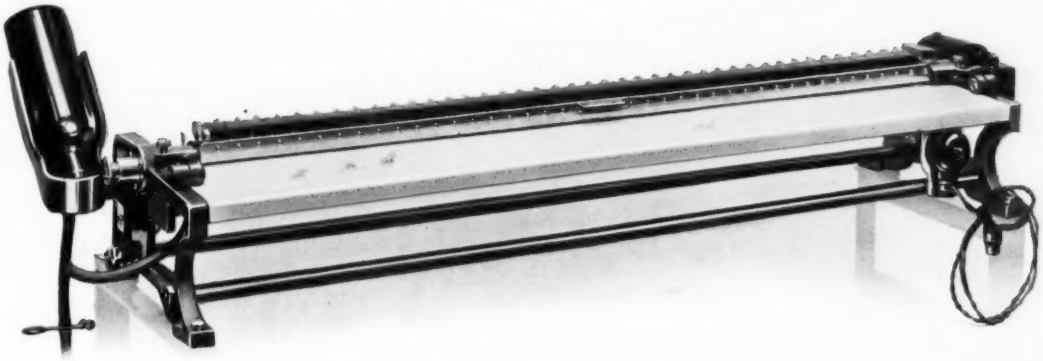

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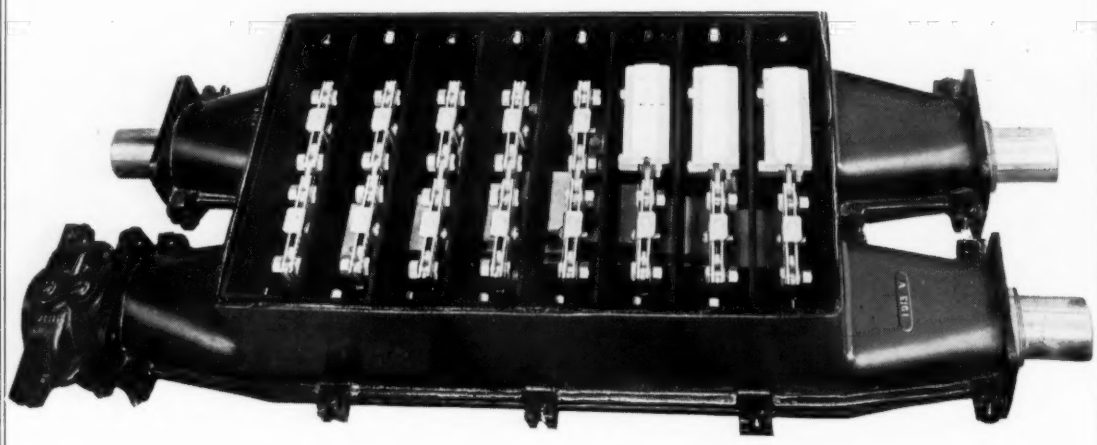

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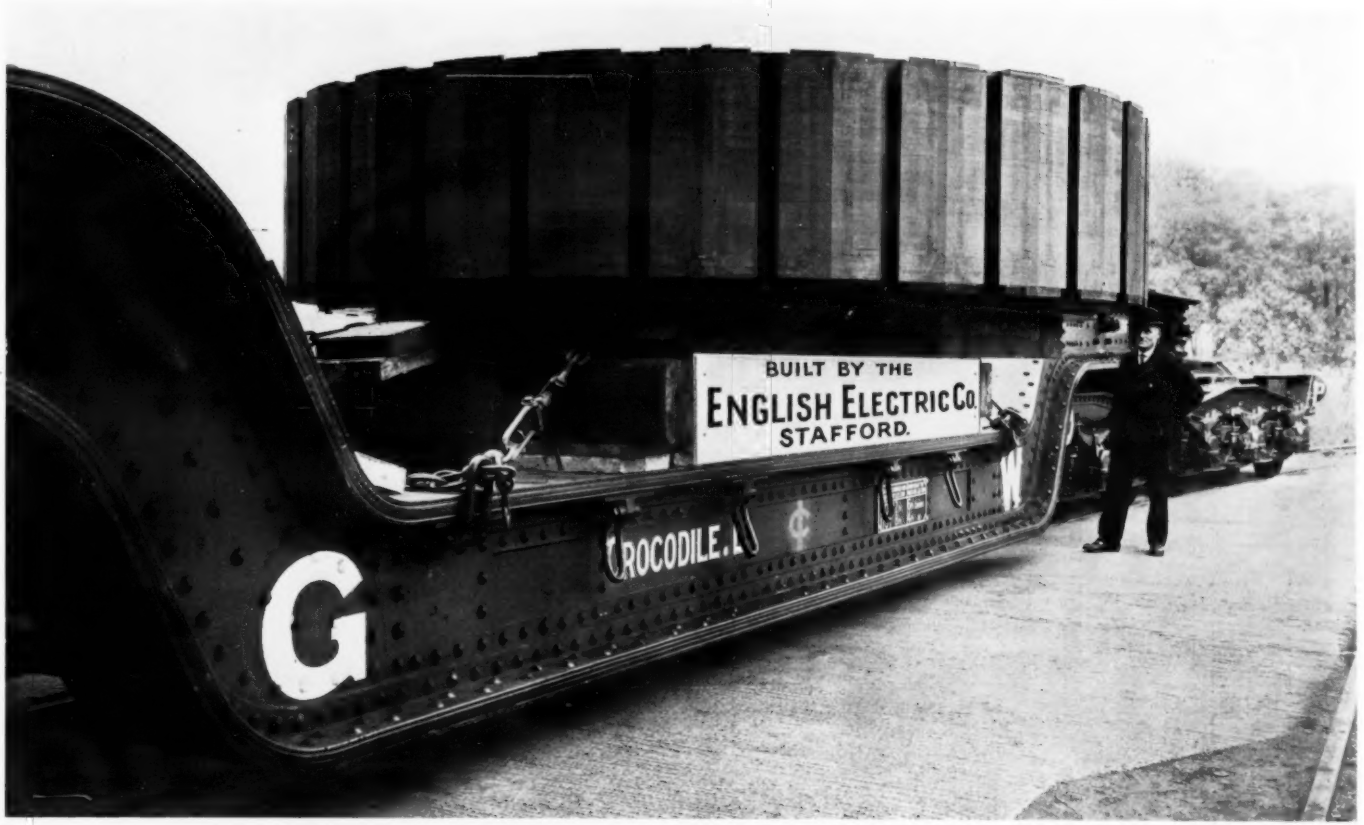

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The English Electric Journal

Vol. VII. No. 2 JUNE, 1934 One Shilling.

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All Communications respecting Editorial Contents should be addressed to The Editor, The English Electric Journal, The English Electric Company Limited, Stafford.

EDITORIAL.

Our frontispiece shows the transport of one of the giant 50-ton Rotors for one of the 11,000-kilowatt, 11,000-volt, 214 R.P.M. Alternators for the Tongland Power Station of the Galloway Water Power Company. This item represents one of the initial deliveries for the complete Galloway Water Power scheme, for which the English Electric Company are supplying the turbine-generating plant aggregating 102,000 kilowatts.

The first article in this issue is devoted to a description of a mercury-arc rectifier having a static grid control, as supplied to the Borough of Wallasey. This type of unit has a wide range of application, and is especially useful where special characteristics are required.

The compounding is perfectly smooth, and in addition the system of voltage regulation used in this type of equipment is ideal for rectifiers operating traction or other rapidly varying loads, as the voltage response is absolutely instantaneous.

The concentration of power plant and the interconnection of supply systems by the "Grid" with the consequent increase in short circuit kVA. available, has made the problem of arc-control of primary importance. Many devices have been developed to solve this problem and we believe the best known and most efficient of these is the "De-ion Grid." This method of arc-control and its application to oil circuit-breakers on various classes of the Company's switchgear is described and illustrated in the second article.

The third article describes the work which the Company has carried out in connection with the supply of electric power to the new Corby Works of Messrs. Stewarts and Lloyds, Ltd. This scheme is of particular interest to the Electrical Industry in that it represents a large scale application of the "National Grid" for industrial power supply purposes.

The increase in the size of modern electric power plants and the multiplicity of circuits to be controlled has rendered the dimensions of control boards of the conventional panel, desk or cubicle type, excessive for convenient supervision. In consequence remote control boards of the "miniature-type" are becoming increasingly popular. A description of the Company's latest practice in this respect is given in the fourth article.

The advantages of the "English Electric" direct generation system, which provides high-tension direct current for the cleaning of industrial gases, are given in the next article. By the courtesy of Mr. J. Bradwell, Manager of the Nunnery Gas & Coke Oven Company, Sheffield, we have been permitted to give some interesting details and figures of the costs and operating results obtained by the use of the Whessoe - Woodall - Duckham Electro Detarrer, incorporating the "English Electric" direct H.T. generation system.

The final article gives a brief account of the official opening ceremony of the Copenhagen Suburban Electric Service on the Danish State Railways. This service has already proved extremely popular, and the Company's equipment has given very satisfactory results.

A Glass Bulb Rectifier Equipment with Static Grid Control.

By J. E. CALVERLEY, M.I.E.E., Chief D.C. Designer, and W. R. EVANS, B.Sc., A.M.I.E.E.

The field of application of the mercury-arc rectifier has been greatly extended by the development of grid control, and improvement in the method of applying this control has placed the rectifier in a very favourable position in cases where special characteristics are required.

Before the application of control grids to the mercury-arc rectifier, the only methods available for compounding the D.C. voltage characteristic were by a tap-changing device on the main transformer, or by an induction regulator operating on the primary or secondary side of the rectifier transformer. In the former method the voltage variation must necessarily take place in steps. In the latter method the voltage variation is smooth between the required limits, the size or capacity of the controlling unit being proportional to the range of D.C. voltage covered by the particular characteristic. The development of the grid-controlled mercury-arc rectifier, on the other hand, has resulted in the production of a compounding conversion unit, which has perfectly smooth voltage control between any desired limits; it is unaffected in size for any voltage range, and is easily adaptable to automatic working. The energy loss in the controlling apparatus itself is small, and thus maintains the high-efficiency feature of the straight rectifier.

The facility with which a grid-controlled equipment can be adapted to give a D.C. supply

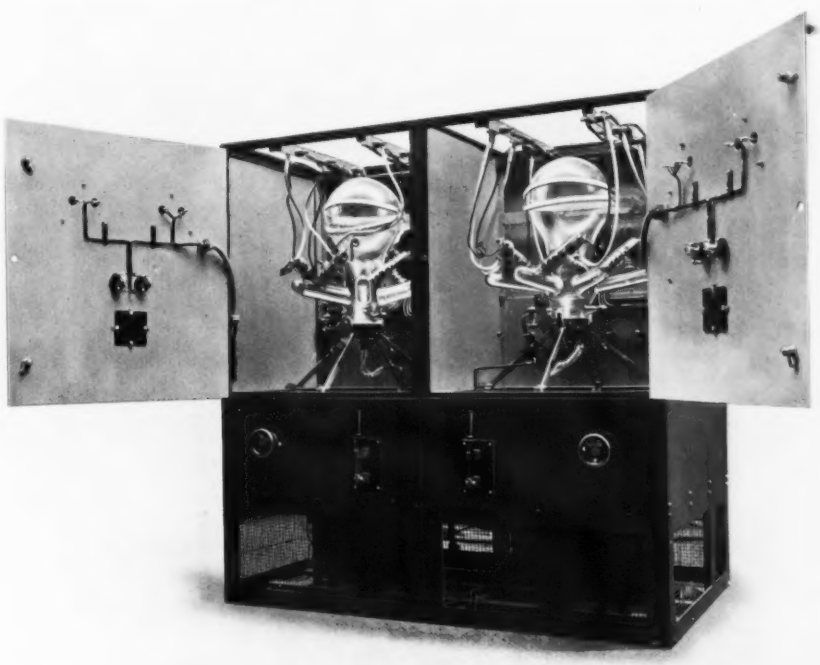


Fig. 1. Showing two 120 kW. Glass-Bulb Rectifiers mounted in Cubicles.

requiring a heavily over-compounded voltage characteristic is exemplified in the glass-bulb equipment recently supplied to the order of the Wallasey Corporation. Previous to the conversion of the tramway system, an outlying pumping station in connection with the Corporation Water Supply was supplied from the traction station through a long feeder. The pumping station contains two motor-driven pumps, which are controlled by means of floats. Voltage conditions on the traction busbars precluded full compensation for the heavy feeder drop, and it was decided to instal a conversion unit which would be sufficiently compounded to maintain normal voltage at the pumps, when the changeover took place.

The equipment, which was manufactured to the specification of Mr. B. T. Hawkins, A.M.I.M.E., A.M.I.E.E., Borough Electrical Engineer, consists of two rectifier cubicles each rated at 120 kW. and each supplied by separate transformers. In order to compensate for the feeder drop and maintain the rated voltage of the pump motors, it was necessary to compound the rectifier to give a no-load voltage of 500, and a full-load voltage of 600, with a mean value of about 550 volts at half load with only one pump in operation.

Although one of the rectifier units is maintained as a standby in view of the importance of the pump-motor load, it was specified that the voltage characteristic of both units should be adjustable between wide limits, to enable either rectifier to feed local circuits in parallel with rotary convertors when occasion demanded.

Each rectifier unit is supplied from a 3/6-phase transformer, the primary supply being 3-phase, 50 cycles, 6,600 volts, and primary taps of $\pm 2\frac{1}{2}$ per cent. and ± 5 per cent. are provided. The transformers are of the oil-immersed type, and incorporate special features in their design necessary for satisfactory operation when feeding rectifiers.

The rectifier cubicles follow the general lines of The English Electric Company's construction in this class of apparatus, and are illustrated in Figs. 1 and 2. The cubicles are arranged for front access, with a voltmeter, ammeter, equaliser switch, and hand-wheel for adjustment of compounding, mounted on the front panel. Each rectifier cubicle contains a 6-anode rectifier bulb fitted with control grids, which is rated at 200 amperes continuously and capable of liberal overloads. Stability of the main arc down to no load is maintained by two excitation anodes fitted near the cathode chamber. Ignition is

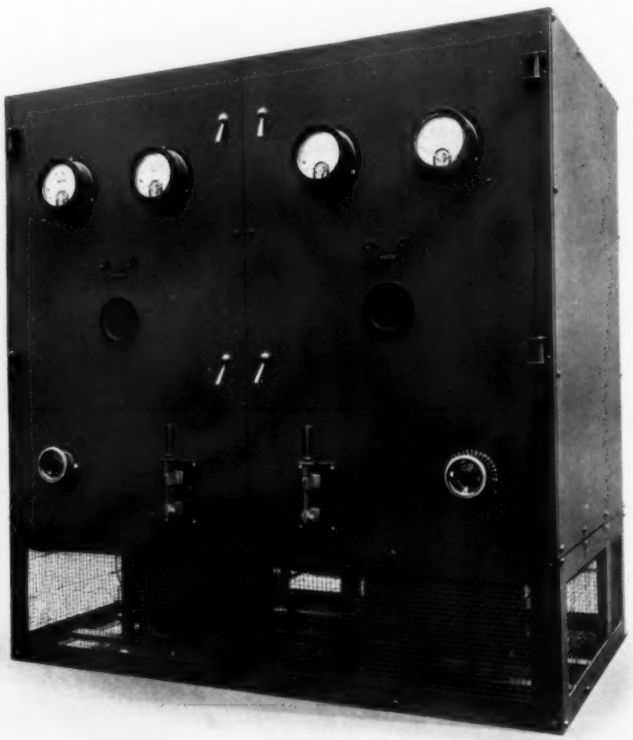


Fig. 2. Front view of Cubicles containing the two 120 kW. Glass-Bulb Rectifiers.

effected by a dipper device, which normally dips into the cathode mercury. When the A.C. supply is switched on, the dipper is raised by the action of a solenoid, producing a small arc which commences ionisation and allows the excitation arc to strike. The ignition circuit is controlled by a relay which opens the circuit when the excitation arc is established.

Cooling of the rectifier bulb is provided by a multi-bladed fan, which is entirely silent in operation. Fuses are incorporated for protection of the anodes. Over-voltage protection is provided by surge-absorbing resistances having a special characteristic. A cathode choke of liberal proportions is connected in the positive lead to ensure a smooth D.C. supply to the motors.

The English Electric Company has developed several methods of grid control ranging from the synchronous impulse type to the completely static type, each of which has its particular advantages. The type of control circuit used in this equipment is the saturated transformer method, the advantages of which, such as its "hard" control, instantaneous response to varying loads, and completely static form without any mechanical movements, have already been described in a previous issue of this Journal. The complete control unit is mounted on a panel and forms a compact arrangement in the upper portion of the rear compartment of the cubicle, as will be seen from Fig. 3. The control panel is shown separately in Fig. 5.

The principles underlying the operation of the control unit may be best described by referring to the diagram of connections shown in Fig. 4. Small highly-saturated transformers are used for providing the impulses to the grids of the rectifier, the instant of ignition being controlled by saturating chokes in which the controlling influence is a function of the D.C. load.

The windings of the saturated chokes are marked 1, 2 and 3, and there are six groups, one per phase. The cores are omitted in the diagram for simplicity. Each of the impulse transformers forming the lower groups has an impulse winding 6 connected to the grids of the rectifier, and two excitation windings 4 and 5, the cores being constructed of high permeability material. A small metal-oxide rectifier provides the negative bias on the grids, and, in addition, exciting current to the pre-magnetising windings of the chokes.

It will be seen from the diagram Fig. 4 that the exciting currents of the impulse transformers have a definite phase displacement, and, further, one

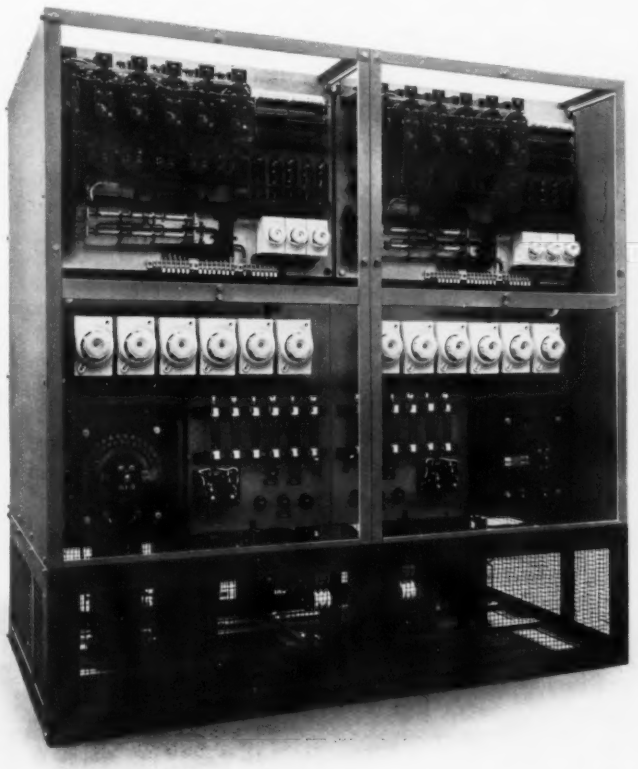


Fig. 3. Rear view of Cubicles showing Grid-Control Apparatus and Anode Fuses.

is maintained constant in value, while the other is varied by the impedance of the choke winding. This feature is shown in the upper portion of Fig. 6, the constant excitation as Ic and the variable excitation as Iv. The resultant excitation will, therefore, be periodic, and the instant of reversal will depend on the relative value of the variable component. In consequence of the high permeability of the core, the flux wave is flat, and at the instant of its rapid reversal will induce a voltage impulse in the grid winding 6. It is possible to limit the duration of the impulse to about 10 deg. by correctly proportioning the various factors in the design, and thus produce an ideal form of "hard" control. The value of the voltage impulse is such that it exceeds the negative bias of the grid relative to the cathode, and at that instant enables the corresponding anode to ignite.

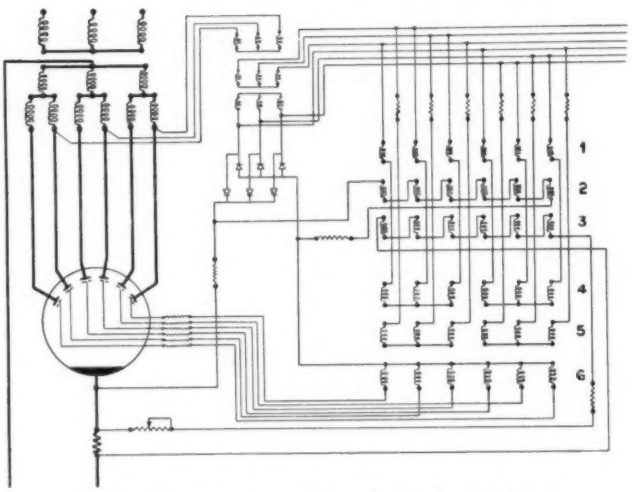


Fig. 4. Diagram of connections of Grid-Control Circuit.

Variation in the value of Iv is produced by the action of the saturating choke, the core of which is pre-magnetised from the metal-oxide rectifier as mentioned before. This pre-magnetisation is neutralised by the ampere-turns of winding 3, which is excited from a shunt in the main positive circuit of the rectifier. The saturation of the core of the choke is, therefore, approximately

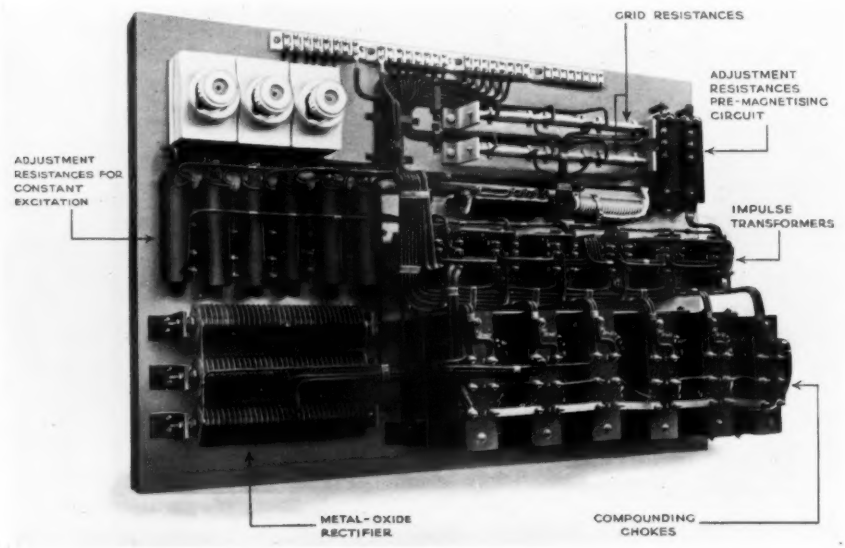


Fig. 5. Grid-Control Panel.

inversely proportional to the load on the rectifier and the variable impedance of winding 1 produces the necessary variation in the value of excitation of the impulse transformer. When the D.C. load increases the variable excitation is weakened, and when the D.C. load decreases the variable excitation is strengthened. Reference to the upper portion of Fig. 6 will show that the effect of this is to move the instant of reversal—or generation of impulse—to the left or right respectively, producing a higher or lower mean D.C. voltage.

In the lower half of Fig. 6 the quantities are shown vectorially, and the relative values with the effect on the ignition angle can be readily seen.

In this diagram—

OA and OA′ represent the anode voltage vector at full load and no load respectively.

A′OA is the angle of ignition advance between no load and full load.

OV, OC are the variable and constant excitation vectors corresponding to full load position.

OV′, OC′ are similar quantities corresponding to no load position.

OR is the resultant excitation at full load.

OR′ is the resultant excitation at no load.

The vectors OV and OC are linked by a constant angle determined by the selected phase displacement between the excitation of windings 4 and 5 of the impulse transformers. It will be seen that the value of the variable excitation must be such that at any instant the projection on the vertical axis must be equal and opposite to the projection of the constant excitation OC. Further, it will be

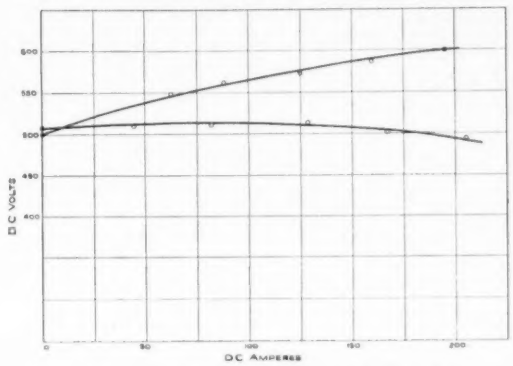
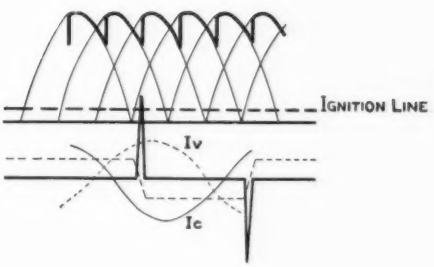


Fig. 7. Curves showing compounding characteristics.



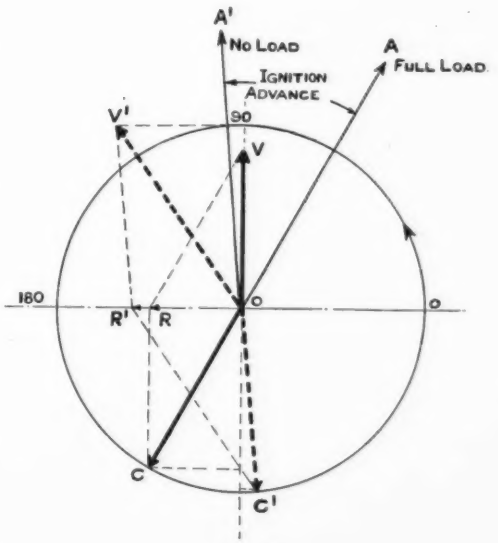


Fig. 6.

observed that the resultant excitation has a value varying between OR and OR′, and that at the instant of ignition the value is zero, at which point the reversal of flux generates the voltage impulse in the grid coils 6. Having determined the amount of ignition advance necessary to give the required increase in voltage for compounding, the diagram will provide the relative values of the constant and variable excitation corresponding to this condition.

A noteworthy feature of this control scheme is the fact that the amount of compounding is under complete control by varying the resistance of the de-magnetising circuit fed from the shunt in the main circuit. The hand-wheel seen on the front of the cubicles controls a rheostat which varies the

resistance in this circuit, so that the compounding is capable of being quickly adjusted to suit the conditions for which this equipment was supplied. In this type of control it is also possible to provide adjustment by which the desired characteristic can be raised or lowered as a whole, which is equivalent to changing the ratio of the main transformer.

Fig. 7 shows the actual test characteristic obtained on this equipment. It will be observed that the compounding is perfectly smooth and has no pronounced " hump," and is, in fact, equal to that obtained on modern converting plant.

The system of voltage regulation used in this equipment is ideal for rectifiers operating traction or other rapidly-varying loads. The voltage response is instantaneous, as there are no relays, contactors or other moving parts which, by their mechanical inertia, inevitably introduce a time lag in the compounding. In addition, the system is also partially self-compensating for variation in the A.C. supply voltage ; and in cases where these variations are of considerable amplitude the scheme lends itself readily to a simple modification which will maintain a steady D.C. voltage in spite of wide fluctuation in the A.C. system.

Any number of bulbs or equipments can be operated in parallel, and current-limiting devices can be provided to prevent excessive overloads without shutting down the plant.

Equipments of this type are available with full automatic features suitable for any required voltage and output, either by traction or industrial power systems.

Modern Oil Circuit-Breaker Design.

By S. E. NEWMAN, A.M.I.E.E., and R. T. LYTHALL.

Circuit-breaker design has undergone very considerable advancement in the past few years. That so many types and designs, which were installed a few years ago, are now being replaced as either obsolete or incapable of performing the duties imposed, is due firstly to the great concentration of power plant and interconnection of systems by the " Grid," with the consequent increase in short-circuit kVA. available, and secondly, because of the greater knowledge of the art and the facilities available for carrying out high-power short-circuit testing under rigorous but recordable conditions.

It is not surprising, therefore, that the greatest effort in respect of improvements in switchgear design should have been concentrated on the oil circuit-breaker. It is only within the last few years that testing plants have been available to prove the interrupting ability of circuit-breakers under the severest possible conditions. Prior to this, ratings were assigned to a circuit-breaker more or less on a " trial and error " principle. Designs were produced and modified, based on the behaviour of the breaker in service, but it was then found that while a given breaker successfully cleared on one system, it would unaccountably fail on another, under what appeared to be identical conditions.

It will be appreciated that results collated by this means do not provide sufficiently reliable data on which to formulate a real basis of design. It was rarely possible, for instance, to install the elaborate apparatus necessary to record the happenings within the breaker structure, such as the rate of rise of recovery voltage, current interrupted, arcing-times, etc., neither in general was it possible to arrange with power supply companies to set aside sufficiently large plants to carry out a series of tests, as these would interfere with the normal supply to consumers. Further, even where this was possible, there still remained the fact that the conditions under short-circuit on the system concerned might be very different from those met with on another system.

It will be seen, therefore, that the results obtained could not be regarded as conclusive, or

that a breaker which satisfactorily functioned on one occasion would do so on the next.

The modern circuit-breaker is now a unit which can be proved to be capable of successfully clearing a specified short-circuit kVA. consistently for any conditions in the system; this is due entirely to the fact that its rating is based on the recorded tests carried out on test plants specially designed to produce conditions of the utmost severity—conditions which are more severe by far than any to be met on any commercial supply system. Such recorded tests can be analysed in very great detail, and the results used with confidence to carry out any modifications necessary to eliminate weakness in the design.

Testing plants of the type referred to can produce an accumulation of power up to one million kVA. or more, at varying voltages.

Perhaps the greatest advance in circuit-breaker design is that resulting in the introduction of arc-control devices. As the name implies, such devices aim at taking control of the arc which occurs on the opening of the breaker. When the contacts in a breaker separate, the arc which is drawn vaporizes the insulating medium with the result that the space between the contacts becomes highly ionised, and its insulating value is so reduced that the arc can persist with a comparatively low potential. The problem of arc rupture, therefore, becomes one of providing means whereby the arc space rapidly recovers its dielectric strength, and it is to this end that arc control devices have been introduced.

The form which these devices take are many; they include the De-ion Grid, Cross Jet, Oil Blast, Gas Blast, etc. In all these, the inherent principle

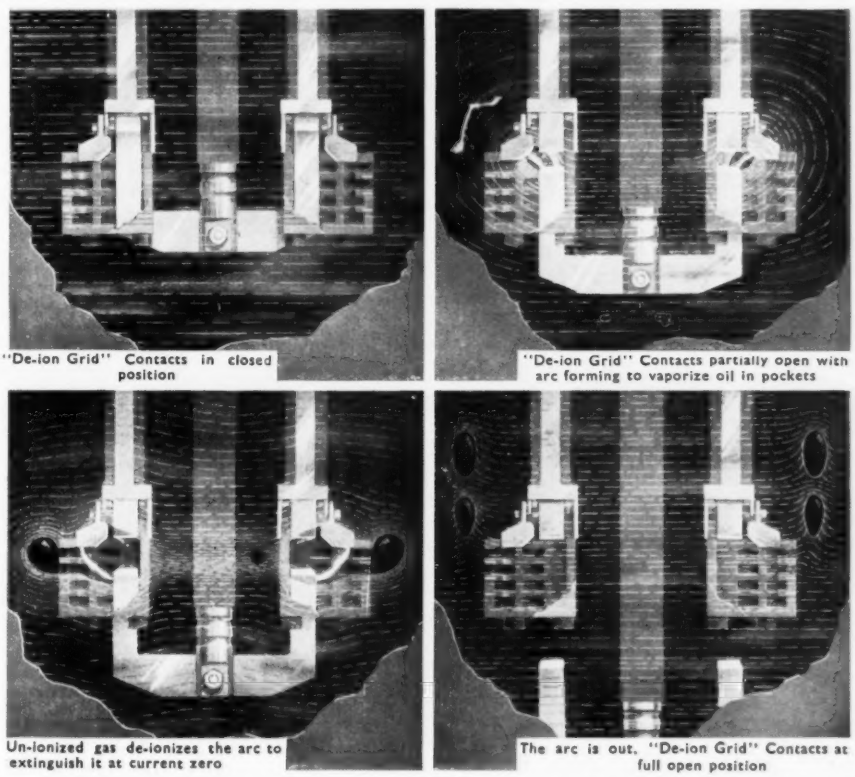

"De-ion Grid" Contacts in closed position
"De-ion Grid" Contacts partially open with arc forming to vaporize oil in pockets
Un-ionized gas de-ionizes the arc to extinguish it at current zero
The arc is out. "De-ion Grid" Contacts at full open position

Fig. 1. Cross sectional views illustrating the action of the "De-ion Grid" during the interruption of the arc on Low Voltage.

is to produce accelerated de-ionisation of the arc space with consequent rapid extinction of the arc without it re-striking, i.e., complete circuit interruption in the shortest possible time.

In an alternating-current circuit, every time the current changes its direction, the flow is zero for an instant. The ideal circuit interruption is that which occurs at the first current zero after the contacts part, and to approach this ideal any arc-control device must not only assist in the de-ionising processes endeavouring to restore the dielectric strength in the arc space, but must commence to act immediately the arc is formed, and continue to act right up to the moment of extinction.

The modern "English Electric" oil circuit-breaker is provided with a device which conforms to these requirements, a device known as the "De-ion Grid."

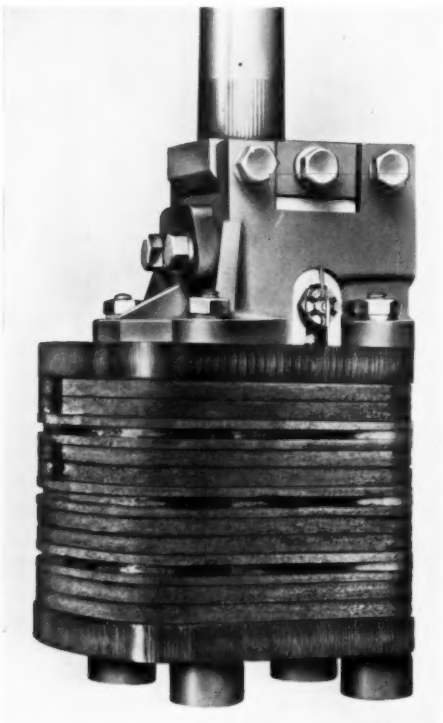


Fig. 2. Typical heavy-duty "De-ion Grid."

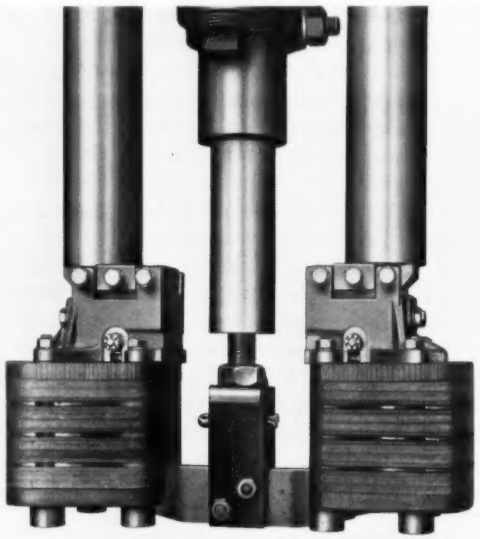


Fig. 3. "De-ion Grid" Circuit-Breaker.

This arc-control device is one which functions as efficiently on high-voltage circuits with relatively low arc-currents, as on low-voltage circuits with high arc-currents.

The "De-ion Grid" utilises to the fullest extent the de-ionising effect of a turbulent flow of gas automatically produced by the arc. As the breaker contacts separate, the arc is drawn into a narrow slot. The presence of iron plates in the grid structure causes the arc to be driven magnetically against the oil, and the arc produces a turbulent evolution of gas which can escape only through the arc. Over a moderate range of short-circuit currents, this turbulent action is sufficient to extinguish the arc with little lateral movement in the grid. When high currents are encountered, however, the arc is driven towards the end of the slot. Here the accumulated gases passing out of the vents subject the entire arc path to a turbulent de-ionising gas flow. As a result, the dielectric strength of the gap at a current zero is raised to the point where the arc cannot re-strike.

Fig. 1 shows cross sectional views which illustrate the action of the "De-ion Grid" during the interruption of the arc on low voltage.

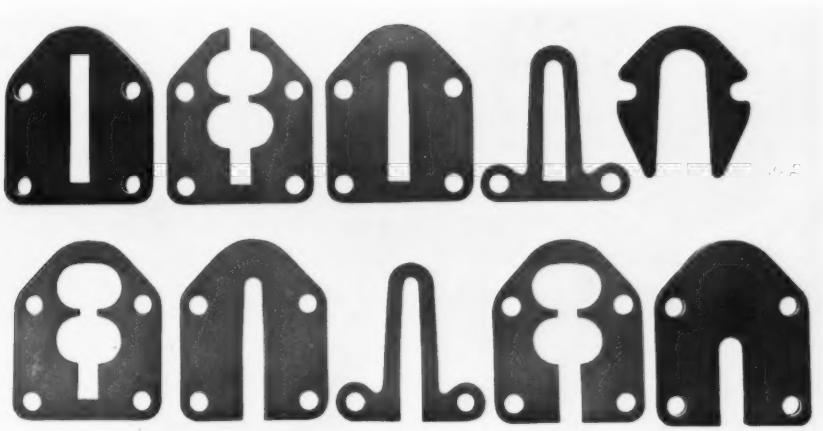


Fig. 4. Series of Elements which form the "De-ion Grid."

Typical "De-ion Grids" of the latest design are represented in Figs. 2 and 3, while Fig. 4 shows a series of the elements forming the stack.

ADVANTAGES OF OIL CIRCUIT-BREAKERS FITTED WITH "DE-ION GRID" CONTACTS.

It is of importance to appreciate that the first duty of an oil circuit-breaker is consistent rapid fault clearance, and that this is definitely obtained by the fitting of the "De-ion Grid" arc-control device. It should also be noted, however, that this device provides benefits in other directions which are of considerable importance to users in a day when "shut-downs," maintenance, etc., must be kept to a minimum.

Briefly summarised, these are :—

(*a*) Oil and contact maintenance reduced by 50 per cent. to 75 per cent.

(*b*) System stability maintained during periods of disturbance.

(*c*) High speed of fault clearance providing greater discrimination of protective gear.

(*d*) Stresses on circuit-breaker structure reduced to very low values.

(*e*) Reduction in space required for a circuit-breaker with given rupturing capacity.

Considering these in some greater detail we find that :—

(*a*) *Oil and Contact Maintenance.*

Little or no burning of contacts is experienced in the "De-ion Grid" breaker, and time and money are thus saved on renewals and maintenance. Similarly, oil deterioration is almost negligible, and cases have occurred in service where a breaker has cleared as many as 36 consecutive short-circuits, and the oil has been found to have properties almost equal to when new. This means a considerable saving over the ordinary breaker where, after two or three short-circuit clearances, a complete change, or at the least, filtering of the oil, is generally found necessary.

(*b*) *System Stability and* (*c*) *High-speed Clearance.*

The effect on system stability during fault clearance, when ordinary breakers are in use, has often been of serious inconvenience both to the undertaking and the consumer, particularly where synchronous machinery is connected to the system.

The short-arcing times of "De-ion Grid" breakers, however, greatly reduces this undesirable effect. Coupled with this, high-speed discrimination can be obtained to the fullest possible advantage by the use of high-speed protective relays.

(*d*) *Stresses in Breaker Structure.*

Despite the more rapid production of gas in the "De-ion Grid" breaker, the pressure rise within the tank, measured during tests, has been found to be remarkably low. In the case of the test illustrated by Fig. 8, the pressure did not

exceed 30 lbs. per square inch. This was on a 250,000 kVA. test, so that commercial circuit-breaker tanks capable of withstanding 100/150 lbs. per square inch have a wide margin of safety. This low pressure is directly attributable to the reduction in arc-length and short arcing-times, with a consequent reduction in arc-energy.

(*e*) *Reduction in Space Required.*

All the above factors tend towards greater efficiency and tests have proved that the accumulation of these factors will permit a definite increase in rated rupturing capacity for a given breaker when fitted with " De-ion Grid " contacts, while retaining the requisite factor of safety.

An example of this increase in rupturing capacity is provided by the type OLD. breaker illustrated in Fig. 14, which has a rated rupturing capacity of 150,000 kVA. without " De-ion Grids," while with the addition of the latter the rated capacity is increased to 250,000 kVA.

Tests.

A very large number of short-circuit tests have been carried out on circuit-breakers fitted with " De-ion Grids," and a selection of these is reproduced in Figs. 5, 6, 7 and 8. These have been analysed and the results tabulated are given below.

ANALYSIS OF OSCILLOGRAMS, FIGS. 5 TO 8.

Fig. No.	Rated Voltage kV	Recovery Voltage kV	Current Interrupted amps	Duration of arc cycles	Total kVA ruptured based on rated voltage
5	11.0	9.36	5,000 4,550 5,500	1.7 1.7 1.5	95,550
6	6.6	6.15	9,950 16,200 16,700	1.0 1.3 1.3	162,800
7	11.0	9.2	14,000 12,990 14,100	1.6 1.4 1.6	261,000
8	11.0	10.6	15,400 16,800 16,900	1.25 1.2 1.0	311,800

From such tests a number of interesting curves have been plotted, and a selection is given in Figs. 9 to 13.

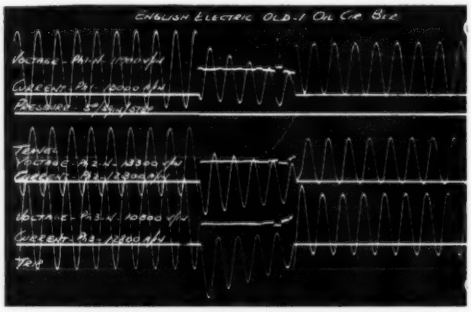


Fig. 5.

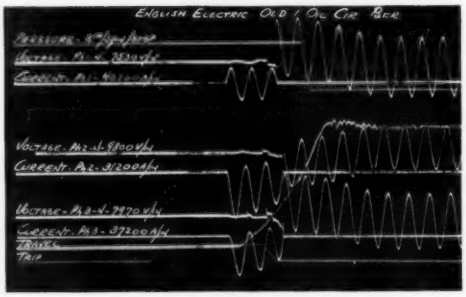


Fig. 6.

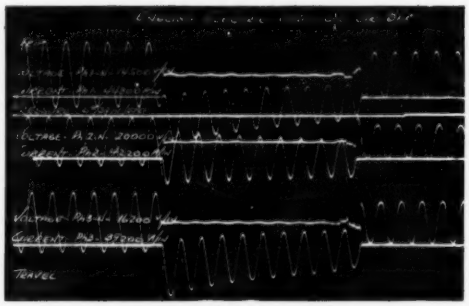


Fig. 7.

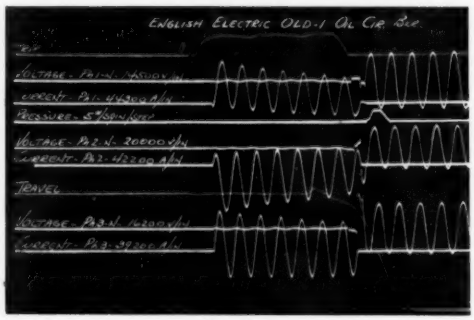


Fig. 8.

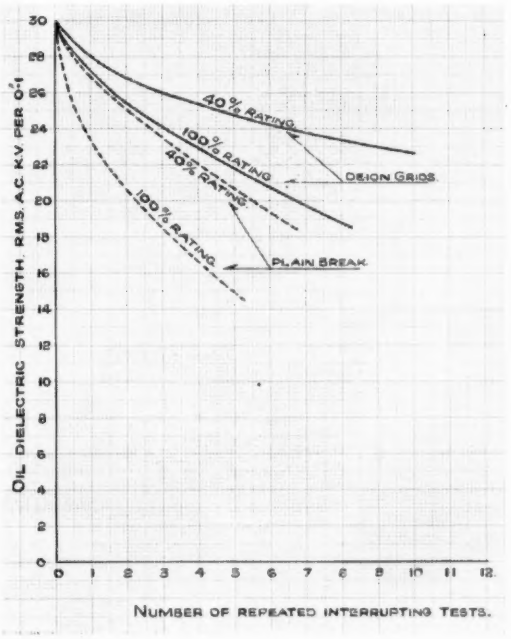


Fig. 9. Showing a comparison between oil dielectric strengths of plain breakers and " De-ion Grid " breakers.

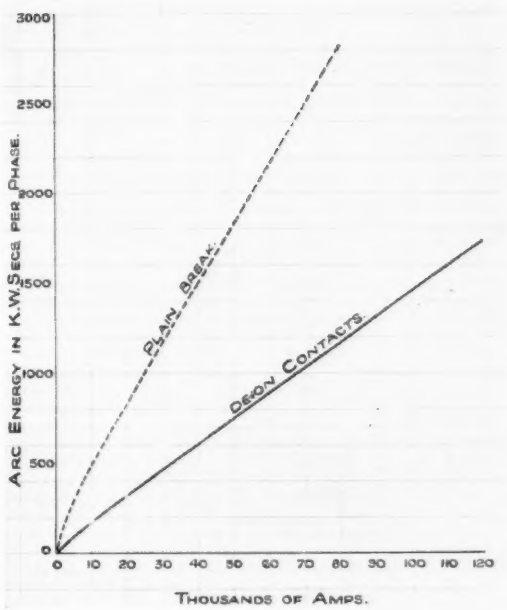


Fig. 10. Shows the reduction in arc-energy in the " De-ion Grid " breaker as against the plain breaker.

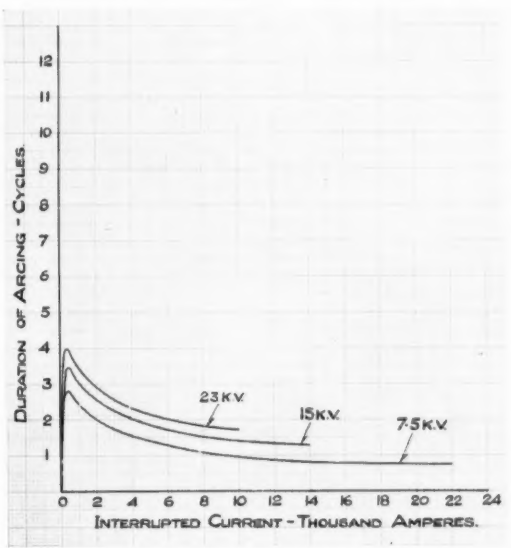


Fig. 11. This curve shows the arcing time (in cycles) of one size of " De-ion Grid " breaker at three voltages. Over the major part of the curves the arcing times are less than 2 cycles.

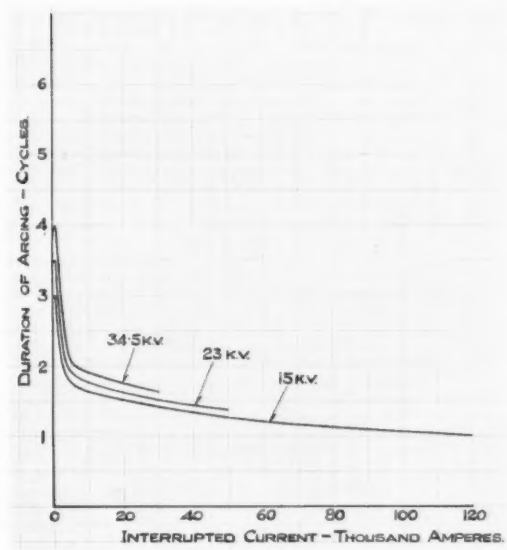


Fig. 12. This curve is similar to the one shown in Fig. 11, but is for another size of " De-ion Grid " breaker.

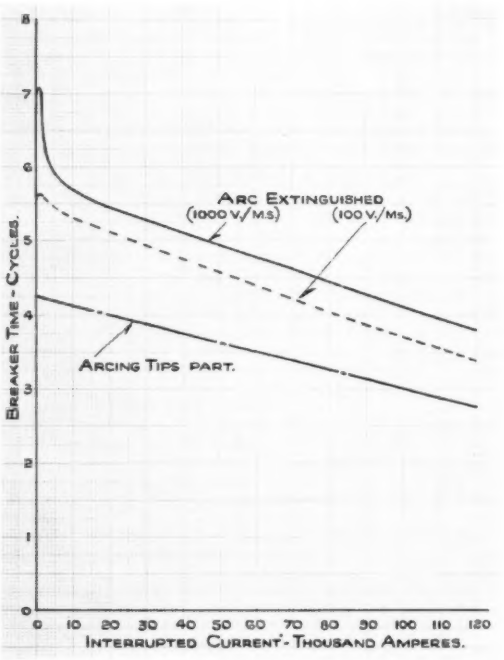

ARC EXTINGUISHED
(1000 V./M.S.)
(100 V./MS.)
ARCING TIPS PART.
BREAKER TIME - CYCLES.
INTERRUPTED CURRENT - THOUSAND AMPERES.
0 10 20 30 40 50 60 70 80 90 100 110 120

Fig. 13. Tests have shown that a "De-ion Grid" breaker is not affected by rates of rise of recovery-voltage between wide limits, and thus consistent performance is established. This curve shows the small difference in arcing times as experienced with rises of 100 and 1,000 volts per micro-second respectively.

Enclosed Operating Mechanism.

A further advancement in design has been in the total enclosure of the breaker operating-mechanism.

With this design the lifting rods, crosshead and other ancillary apparatus of a 3-phase unit, are located in the air space directly below the breaker top plate, thereby avoiding the unequal pressures liable to be exerted on the moving portion where part of the mechanism is located externally to the top plate. In this latter arrangement the lifting rods passing through the top plate are liable to give rise to "piston effect," tending to arrest the opening motion of the breaker.

The enclosed mechanism also has advantages in eliminating lubrication troubles, and results in a more pleasing design.

Methods of Electrical Operation.

Circuit-breakers for many years have been operated by solenoid or motor mechanisms, the former involving the installation of a large operating battery, the latter demanding the existence of a low voltage A.C. or D.C. supply.

Motor-operated breakers have the further disadvantage that they are either slow in operation or require special inertia storage by flywheel or other means. Where it is not essential to operate circuit-breakers from a standby battery, a metal rectifier of the oxide-film type and D.C. solenoids may now be employed in place of motor drive.

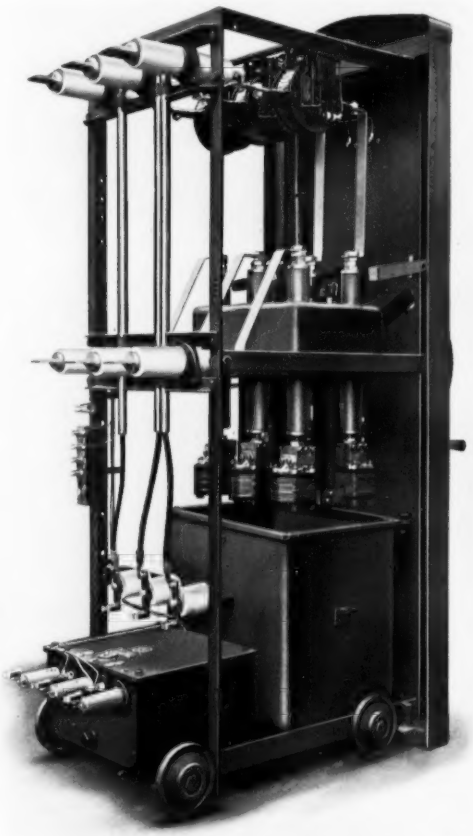


Fig. 14. Truck type Cubicle, Rupturing Capacity 250,000 kVA.

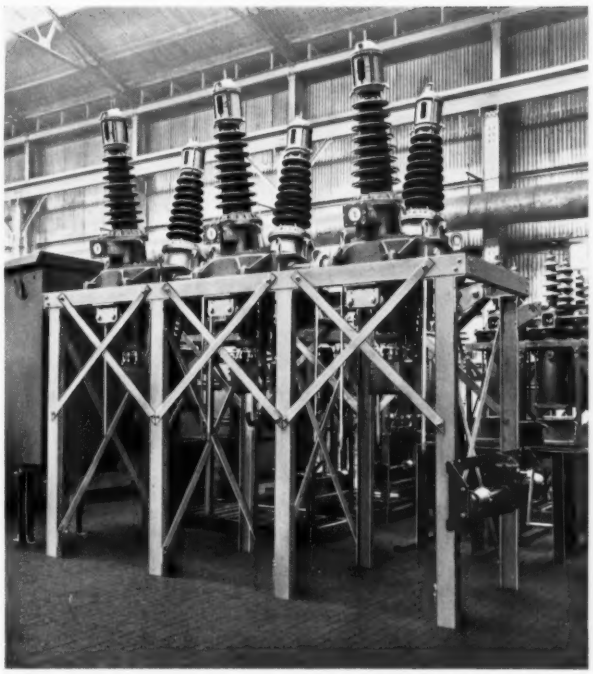


Fig. 15. Modern outdoor type Oil Circuit Breakers with "De-ion Grids."

position, no foundations being necessary. The saving in the omission of a battery and its upkeep, together with the avoidance of a room set apart for its accommodation need not be stressed. It is usual to design the solenoid to suit the rectifier voltage and so avoid the necessity of a transformer, and it is interesting to note that the rectifier actually provides a discharge path for the inductive energy of the solenoid.

Current Transformers.

In the past, careful attention was not always given to the design of current transformers to ensure that they were capable of withstanding the disruptive forces resulting from short-circuit currents. The importance of this factor is accentuated in modern switchgear having a high rupturing capacity, and

A number of oil circuit-breakers employing rectifier operation are now in service, a recent example being the 33 kV. breakers at the Kettering U.D.C. outdoor transforming station, described elsewhere in this Journal.

The metal rectifier needs no attention or maintenance; moreover, being a static piece of apparatus, it may be fixed in any convenient

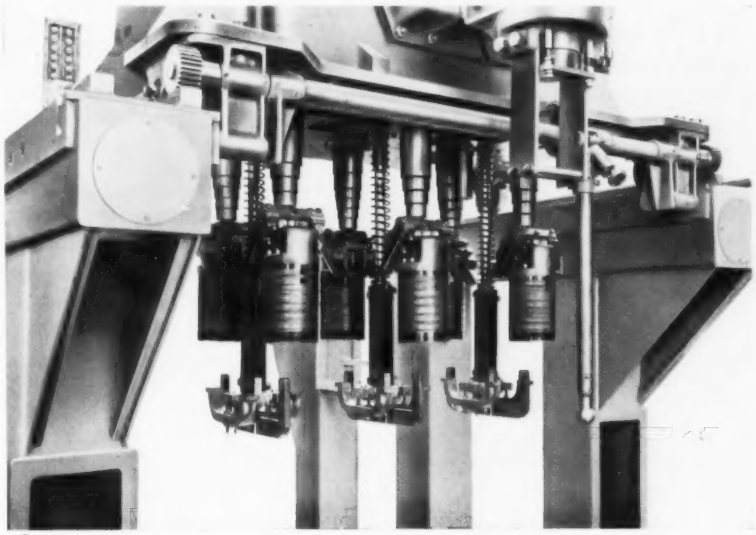


Fig. 16. Part view of 33 kV. Metalclad Unit showing heavy duty "De-ion Grids" and Moving Contact system. Rupturing Capacity 750,000 kVA.

current transformers are specially designed to withstand the maximum stresses to which they may be subjected under the severest fault conditions.

In switchgear of higher rupturing capacity, bar-type primaries are employed, and where primary currents are small, resort is made to special nickel-iron cores having a high permeability.

Typical Examples of Modern Switchgear.

It would be impossible to illustrate, in the space available for this article, a comprehensive range of modern switchgear units, but the illustrations Figs. 14, 15, 16, and 17, are given as examples of "English Electric" switchgear.

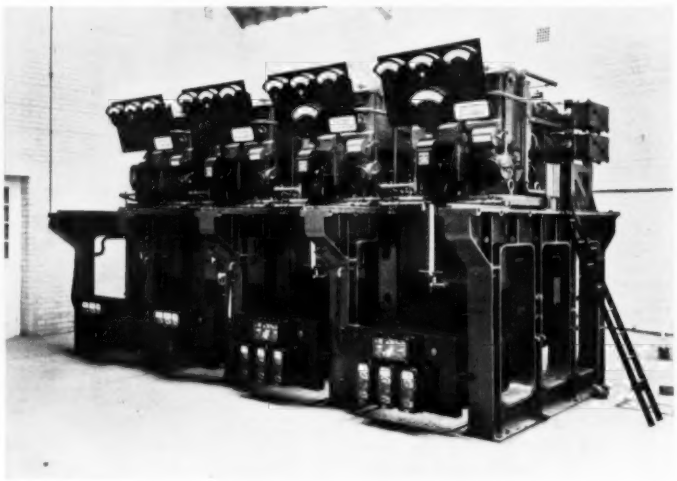


Fig. 17. Modern 33 kV. Metalclad Compound filled Switchboard, 500,000 kVA. Rupturing Capacity.

Supply of Electric Power to Messrs. Stewarts & Lloyds Ltd., Corby.

The English Electric Company have recently completed an important contract for the necessary switchgear and transformers for the supply to the new Corby Works of Messrs. Stewarts & Lloyds Ltd. The project is of particular interest to the Electrical Industry in so far that it represents a large scale application of the National Grid for industrial power supply purposes.

The Central Electricity Board's Transforming Station at Northampton is connected to the main 132 kV. transmission lines from Hams Hall, Warwick, and Bedford. From this point energy is transmitted at 33 kV. through existing transmission lines to the power station of the Northampton Electric Light and Power Company, which, in turn, is interconnected to the power station of the Kettering U.D.C. At the latter station a 10,000 kVA. transformer bank, recently supplied by The English Electric Company, is reserved for feeding a cable circuit connecting to a new C.E.B. Switching Station at Rothwell Road, Kettering.

In addition, two new 33 kV. transmission lines have been constructed for the C.E.B. from Northampton Transforming Station direct to Rothwell Road Switching Station. From this point two 33 kV. transmission lines under the jurisdiction of Kettering U.D.C. run for some eight miles to Messrs. Stewarts & Lloyds' Corby Works.

The 33 kV. transmission lines terminate in Messrs. Stewarts & Lloyds' Works at an outdoor switching station supplied and erected by The English Electric Company to the order of the Kettering U.D.C. Here, pressure is stepped down to 11 kV. and taken by cable to the Main Indoor Substation housing two 11 kV. metalclad switchboards of the Company's OLD.1 type units.

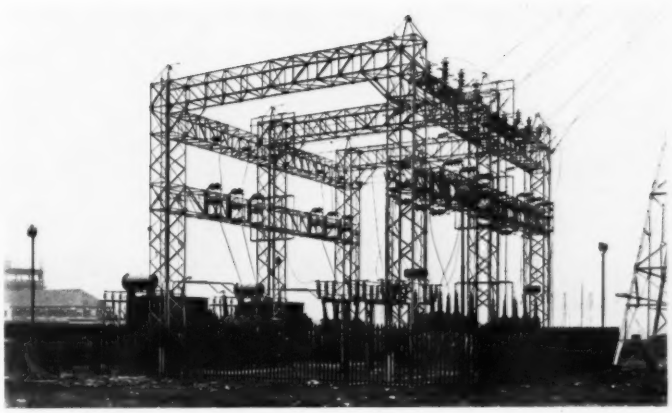


Fig. 1. 33 kV. Outdoor Switching Station of the Kettering U.D.C.

One switchboard has been supplied to Kettering U.D.C., and the other to Messrs. Stewarts & Lloyds. The latter board controls the supply to the steel works distribution Substation, which takes the form of two ring main systems. In the first ring are connected the Blast Furnace, Coke Ovens, and Bessemer Substations, and in the second the Blooming Mill, Skelp Mill and Tube Plant Substations. The 11 kV. switchgear for the substations is also of the Company's manufacture and similar to that installed at the Main Indoor Substation.

Outdoor Switching Station.

A general view of the switching station is shown in Figure 1. From the illustration it can be seen that the latticed column type of construction has been adopted for the structure, and that the circuits are laid out in two separate sections with the necessary screening and access ladders. The switching layout is such that a complete section or part thereof, may be isolated and made safe for inspection and maintenance purposes without causing interruption of supply which may be maintained by the remaining section. Isolating and disconnecting switches are of the centre rotating post type, with remote operating mechanisms suitable for working from the ground level. The oil circuit-breakers are of type OKD.2, having a rupturing capacity of 500,000 kVA., and are fitted with De-ion Grid Contacts.

Surge absorbers have been provided for the incoming lines, and the station apparatus shielded from the effects of lightning surges by overhead guard wires. A uniform level of insulation values is provided for the station switchgear which is co-ordinated with the line insulation by means of grading the strings of the three home towers.

The conductors for busbar connections are mostly of the stranded Bolton type, although in certain cases tubular copper rods have been used. In the latter instance, expansion joints and swivelled connectors are used for avoiding the application of direct stresses to oil circuit-breakers and transformer terminal bushings. The multicore cables used for control and protective gear circuits, and for isolating switch indication are run and cleated to the sides of reinforced concrete ducts, which have removable top slabs for inspection purposes.

An interesting feature of the station from a civil engineering point of view is that it is built on recently tipped ground, and as a result it was necessary in certain cases to drive piles down to 30 feet on which to erect the concrete bases for the apparatus and structures. The piles are of the reinforced concrete type and were cast *in situ*.

Despite the fact that construction took place during the winter, the work was completed in accordance with the general programme for the whole scheme. The shortness of daylight during this period was partially offset by the use of temporary flood-lighting equipment.

INDOOR SUBSTATION.

The control board for the 33 kV. switchgear is housed in the main indoor substation. An interesting feature of the control of the 33 kV. oil circuit-breakers is that A.C. power is obtained from the station auxiliary transformer and taken to the outdoor substation for conversion to D.C. by means of a Westinghouse metal rectifier. This enables the operating mechanism of the oil circuit-breakers to be of the standard solenoid type and dispenses with the usual large station battery for this duty. For tripping purposes a 50-volt D.C. battery is installed, which is trickle charged by means of a metal rectifier also fed from the auxiliary station circuits. The circuit-breakers are of the miniature type with thermal and magnetic overcurrent releases. The primary of the station auxiliary transformer is controlled by an "English Electric" 11 kV. oil-immersed switch-fuse.

Fig. 2. 7-Panel, 11 kV. Type OLD.1b Metalclad Switchboard for the Kettering U.D.C.

The 11 kV. metalclad switchboard supplied to Kettering U.D.C. is shown in Figure 2. It is of the type OLD.1b, having duplicate busbars and oil circuit-breakers with a rupturing capacity of 250,000 kVA. The oil circuit-breakers are fitted with De-ion Grid Contacts. At each end of the board, connection is made to the busbars by means of an oil immersed isolating switch, which is used to control the supply to the station transformer. Before the completion of the outdoor switching station this switchboard was used to control a temporary 11 kV. feed from the existing Kettering U.D.C. system.

Fig. 3. 9-Panel, 11 kV. Type OLD.1b Metalclad Switchboard for Messrs. Stewarts & Lloyds.

The Works' Feeder equipments of this switchboard are directly connected to the incoming equipments of Messrs. Stewarts & Lloyds' switchboard, which is shown in Figure 3. This latter switchboard has oil circuit-breakers similar to those already mentioned, although in this case single busbars are employed.

Seven distribution substations in the Steel Works have been equipped with similar switchgear, and "English Electric" power transformers ranging from 750 kVA. to 3,000 kVA. are used for stepping down pressure to 3,300 volts and 415 volts.

Prompt delivery being an essential feature of these combined contracts, it is noteworthy that the order for the outdoor switching station was received on 12th October, 1933, and complete erection on site was effected by 14th March, 1934. The 33 kV. supply was first switched on on the 21st March, for provisional purposes, and on 28th March for permanent supply.

The order for the Kettering U.D.C. 11 kV. switchboard was received on 12th October, 1933, and the board was despatched on the 10th December, 1933. Similarly, the orders for Messrs. Stewarts & Lloyds' switchgear for the main and distribution substations were received on 18th October, and the completed gear was despatched on 15th December, 1933. This enabled all cable connections and testing arrangements to be completed for supplying power to the works by 1st January, 1934. In addition, the switchboard for the Bessemer Substation was completed by 4th January, thus affording the further advantages of the initial 11 kV. power supply.

It should also be noted that "English Electric" transformers of 750 kVA. capacity were utilised in this initial scheme and were supplied under the same short delivery programme.

Summarising, the work undertaken by the English Electric Company comprised :—

For Kettering U.D.C. (Consulting Engineers, Messrs. Arthur Ellis & Partners).

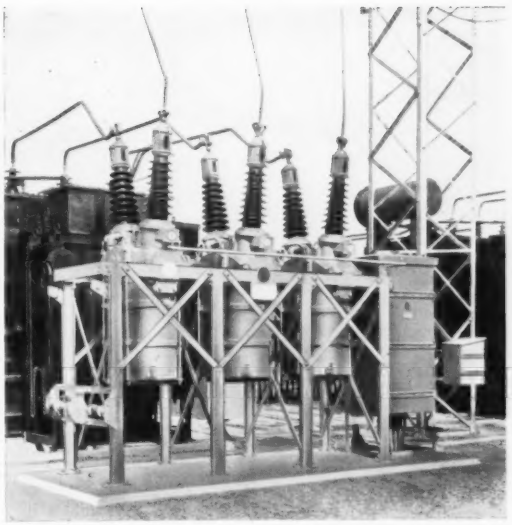


Fig. 4. Showing one of the 33 kV. type OKD.2 Outdoor Oil Circuit Breakers, 500,000 kVA. rupturing capacity.

33 kV. Outdoor Switching Station.
11 kV. Main Switchboard of 9 units.
440-volt Auxiliary Switchboard.

For Messrs. Stewarts & Lloyds (Consulting Engineers, Messrs. H. A. Brassert & Co.).

11 kV. Main Switchboard, 12 units.
11 kV. Distribution Switchboards totalling 32 units. (The number of OLD.1 type pillars totalling 53.)
11- 750 kVA. 11,000/415-volt Transformers.
1-3,000 kVA. 11,000/3,300-volt Transformer.
1-1,500 kVA. 11,000/3,300-volt Transformer.

In addition to the main contract work outlined above, the Company have recently received a further order for four metalclad pillars, type OLD.1, for extensions to the Tube Plant Works.

Miniature-Type Remote Control Boards.

For the efficient operation of large electrical switching installations it is essential that the control of all switchgear and important associated plant shall be placed under the immediate supervision of one engineer, and although for this purpose remote control boards for the electrical operation of switchgear have been in use for many years, the size of modern electric power plants and the multiplicity of circuits to be controlled tend to render the dimensions of control boards of the conventional panel, desk or cubicle type excessive for convenient supervision. The space occupied by such boards is also a factor of importance in many cases.

It was formerly the accepted practice to mount on the control board not only the control and

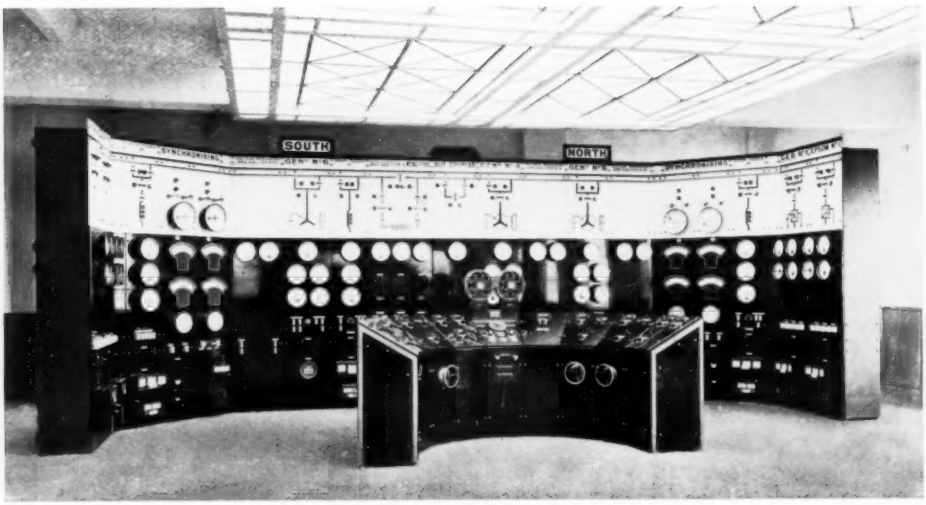


Fig. 1. Typical Cubicle type Control Board with desk-type Generator Control Board in Foreground.

indicating devices and instruments, but also all meters, protective relays, etc., associated with the switchgear controlled; although this arrangement is quite satisfactory for the smaller installations, it has now become general in the case of large stations to locate all integrating meters, relays and recording instruments on separate boards, and thus confine the equipment of the control board proper to such apparatus with which the control room engineer is immediately concerned when performing switching operations. Even when this arrangement is adopted, a conventional control board for a large number of circuits often becomes somewhat unwieldy.

A typical example of a power station control room with a desk-type generator control board in the foreground and the main cubicle-type control board in the background is shown in Fig. 1. These two boards jointly control a 17-unit 6,600-volt duplicate busbar metalclad switchboard having a breaking capacity of 1,000,000 kVA., a section of which is shown in Fig. 2.

The approximate overall dimensions of the main control board are: Height 10 ft. 4 ins., depth 2 ft., and developed length along front 37 ft. 3 ins., and those of the generator control board 4 ft., 2 ft., and 9 ft. 6 ins. respectively. The protective relays in this instance are mounted on the main control board, but all integrating meters are placed on a separately located meter board.

The considerations outlined above have led this Company to develop the "miniature-type" remote control board, of which a typical example in course of assembly, is shown in Fig. 3. The approximate overall dimensions of this board are: Height 5 ft. 6 ins., depth 3 ft. 3 ins., and developed length along the front 11 ft. It is to control a 22-unit 33 kV. duplicate busbar metalclad switchboard with a breaking capacity of 750,000 kVA., including 3 (eventually 4) 25,000 kW. alternator units. The saving in space effected by the "miniature-type" board is evident on comparison with the conventional cubicle and desk type boards referred to in the preceding paragraph. Further, switching operations and general supervision are greatly facilitated by the compact nature of the board and the consequent proximity to the operator of all control switches, indicators and instruments.

The standard "miniature" control board is constructed of steel panels mounted on self-supporting welded-steel framework, the back and ends being totally enclosed by removable steel covers. The finish of the panels shown in Fig. 3

is dull green, all control switches are chromium plated, and the instrument facings are enamelled black. Alternative standard finishes are available.

The mimic diagram, showing the circuits controlled, is marked with coloured metal strips laid on the face of the sloping panels; the control switches for the oil circuit-breakers, indicating-lamps and lamp-type semaphore indicators being inserted in their appropriate positions in the diagram. Fig. 4 shows a near view of a group of typical panels. The protective relays, integrating meters and recording instruments are mounted on separate panels for convenient location in the control room.

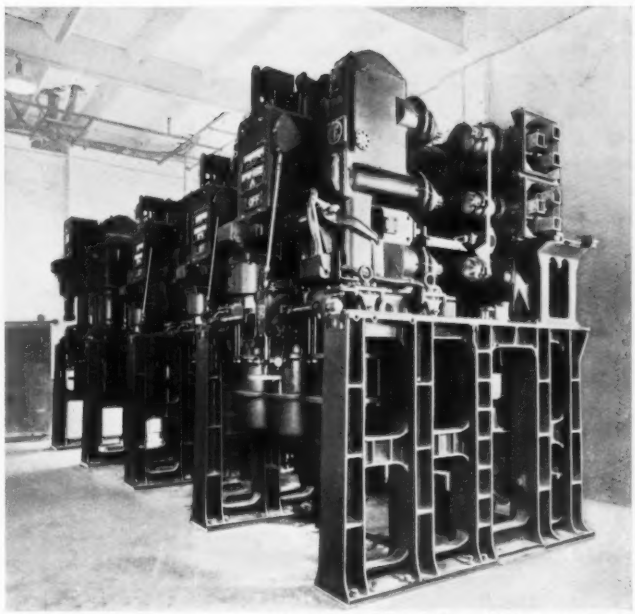


Fig. 2. Section of 17-Unit 6·6 kV. Metalclad Switchboard 1,000,000 kVA. Rupturing Capacity, controlled from board shown in Fig. 1.

All control and instrument switches are of the drum-type standardised by this company, those for the oil circuit-breakers and turbine governor or rheostat operating motors having a spring return to the neutral position. In addition, the control switches for the oil circuit-breakers have a sequence interlock, to prevent two "close" motions being made in succession without first moving the switch to the "trip" position, and also a locking device consisting of a key located in the boss of the handle, which can be withdrawn only when the switch is in the "trip" position, and which, when withdrawn, locks the switch in that position. The same key fits a padlock

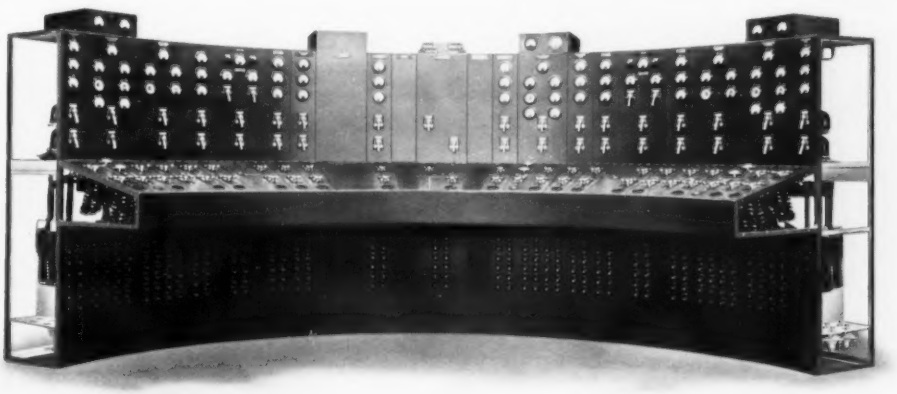


Fig. 3. "Miniature-type" remote Control Board for electrical operation of a 22-unit, 33 kV., duplicate-busbar type OLG-1A Metalclad Switchboard, Rupturing Capacity 750,000 kVA. Board shown in course of assembly.

on the corresponding switch unit, thus providing an effective safeguard when carrying out maintenance work.

Synchronising between any two circuits is effected by means of instrument switches on the panels concerned; such switches are shown in two rows on the top vertical panels in Fig. 4. Turning a switch in one direction connects the circuit through bus wires to one winding of the synchroscope and one voltmeter, and turning the switch in the opposite direction connects the circuit through a second set of bus wires to the other winding of the synchroscope and the second voltmeter. In order to prevent more than one circuit being connected to the same set of synchronising bus wires, the following key-interlock is provided. Two keys of the Yale pattern are provided for the control board, one labelled "running" and the other "incoming." Each synchronising switch is fitted with two corresponding locks, one passing the "running" key and the other the "incoming" key. A synchronising switch cannot be moved in either direction until the appropriate key is inserted and turned in its lock, and the key is trapped when the synchronising switch is moved and can be released only by moving the switch to the neutral position. A synchronising switch moved to the "incoming" position, and with the key inserted, is shown in Fig. 4.

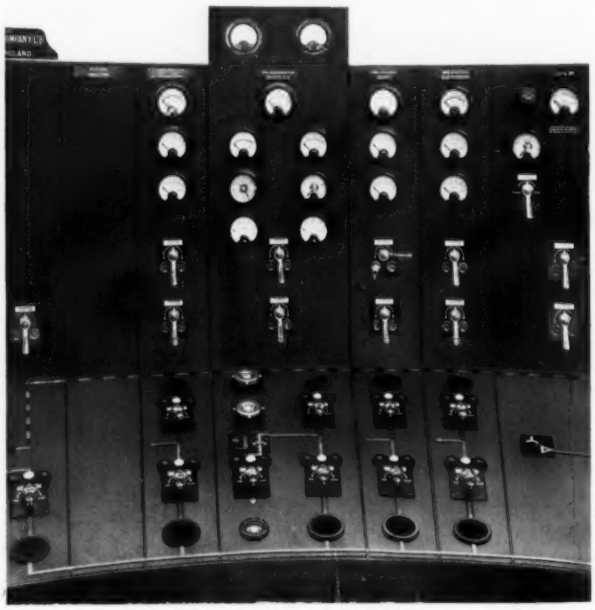


Fig. 4. Near view of Group of Panels of "Miniature-type" Remote Control Board.

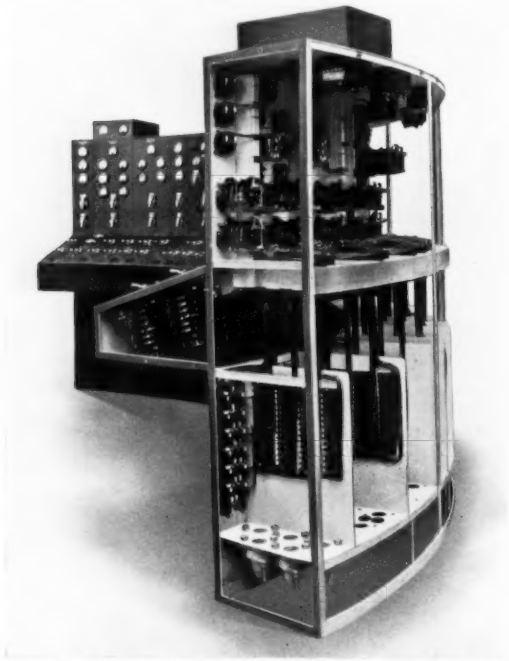


Fig. 5. End view of "Miniature-type" Remote Control Board with covers removed.

The indicating instruments are of the flush-mounting pattern having B.S.S. first grade accuracy and available with either $2\frac{1}{2}$ in. or 4 in. diameter dials. The instruments shown on the accompanying illustrations have $2\frac{1}{2}$ in. dials, the scales being very clearly marked, so that they can be read with ease several feet away from the board.

The small wiring is arranged in a very neat and systematic manner, as will be seen from the example illustrated in Fig. 5, each individual wire being provided with a numbered ferrule, having a corresponding number on the terminal boards. This, together with the use

of standard phase colouring, greatly facilitates the tracing of circuits. Bus wires, such as those for synchronising, are run in a horizontal plane and are provided with a terminal block for each panel. The terminal boards are mounted on vertical steel partitions between the panels, these, and the glands for the external multicore cables, being clearly shown in Fig. 5.

The fuses for the control, indicating and instrument circuits are of the "English Electric" "DB" flush-mounting enclosed cartridge-type having a guaranteed rupturing capacity of 25,000 kVA. They are provided with visual indicators, in the form of coloured discs visible through glazed holes in the fittings, showing when the fuse element has blown. The fuses are shown in Fig. 3 mounted on the bottom front panels of the control board, but alternatively they can be located on the separate relay and metering panels.

The switchboard shown in the accompanying illustrations is to be fitted with a polished teak writing desk at each end.

The appearance of the "miniature" control boards is excellent, and there is no doubt that their practical advantages will commend them to an increasing number of electrical power engineers in the future.

The "English Electric" System of Electrical Precipitation.

By W. DONNELLY, B.Sc. (Tech.), A.M.I.E.E.

The development of the "English Electric" direct generation system providing direct current at high voltage for the cleaning of industrial gases was referred to in the October, 1932, issue of this Journal. Since that date several equipments have been put into service, and there is abundant evidence that the market is expanding rapidly. The "direct generation" system is making a wide appeal to engineers on account of its reliability and simplicity.

The possible uses of electrical precipitation are innumerable, but the following will serve as a general indication of the wide field of application :—

Dust Removal.

Blast furnace gas.
Flue gas from all furnaces.
Cement, phosphate, pyrites and all burner or kiln gases.
Chemical industry gases.
Effluent air from crushing, grinding, screening and drying plants.

Mist Removal.

Sulphuric and other acid plants and chemical plant gases generally.

Fog Removal.

Coal and coke-oven gas.
Carburetted water gas.
Producer gas.
Low temperature carbonisation gas.
Oil refining gases.

Fume Removal.

Smelter, roaster and other metallurgical gases.
Chemical plant gases.

In the past, particularly in this country, the process has not been used to the extent warranted by its superiority over alternative systems. To a large extent this has been due to the lack of a really suitable method of providing the necessary direct current.

This difficulty no longer exists, and those responsible for controlling processes to which electrical precipitation can be applied are realising the fact that this ideal method of cleaning is a practical commercial proposition.

The actual cleaning of the gases is effected by passing the crude gas between electrodes maintained at potentials differing by 20 to 60 kV. One electrode is at earth potential and is usually in the form of a series of vertical tubes or plates. The high-voltage electrodes comprise a number of wires or rods suspended in the axes of the tubes or midway between the plates. The discharge occurring from the high-voltage electrode results in the deposition of the suspended particles in the gas, leaving the clean gas to pass out free from these impurities. It is found that for the greatest efficiency a constant voltage is necessary, and that the discharge electrode should be negative. With negative potential, discharge occurs at a lower voltage and deposition is mainly on the earthed electrodes.

It is outside the scope of the present article to discuss the many interesting phenomena encountered in the various applications of the cleaning process ; accordingly, this description is confined to the method of producing the high-voltage required—20 to 60 kV., the current consumption being 50-500 milli-amps.

Based on the Company's twenty-five years' experience in the manufacture of high-voltage generators for wireless work, a novel form of generation has been developed. The objective has been to combine the following important features :—

(1) Freedom from complicated systems of chokes and condensers. Ease of maintenance and, what is equally important, readily understood by a works' maintenance electrician.

(2) All control on the low-tension supply with no high-tension switchgear.

(3) Easy voltage regulation whilst the plant is in operation.

(4) Straight line wave form to give maximum efficiency of cleaning at the lowest voltage, combined with freedom from interference with wireless.

(5) Ability to cope with short-circuit conditions.

The method adopted is illustrated in Figs. 1 and 2, which show a two-generator unit for 30 kV.

A motor to suit any supply—A.C. or D.C. or any prime mover—drives two generators. The frames of these generators are insulated from earth by suitable porcelain supports, from the motor and from each other by insulating couplings. The two generators are connected in series. Each generator develops 15 kV., and has two high-tension windings and commutators in series. By the patented system of potential grading, involving the connection of the mid-point of the windings to the frame, the maximum stress between the winding and the core is reduced to 7.5 kV. peak value.

The high-tension windings themselves are so

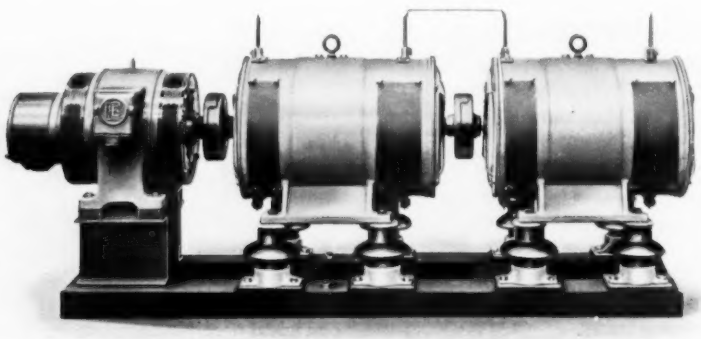


Fig. 1. Motor driven Two-Generator set for 30,000 volts D.C.

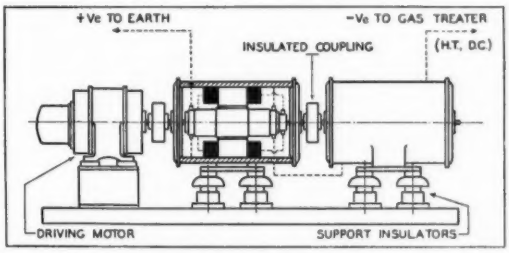


Fig. 2. Part sectional view of two-generator set.

arranged that the potential between adjacent coils of different windings cannot exceed 7.5 kV.

Each generator is self-excited, the field being supplied from a third commutator connected to an independent winding placed at the bottom of the slots beneath the high-tension winding insulation. Since this winding develops only 20 volts, its insulation from the core presents no difficulty, and the field winding of sturdy section copper at the same low potential, is equally free from insulation difficulty. No field connections are brought outside the frame, voltage adjustment being provided by a resistance internally mounted.

A very valuable characteristic of these generators is their behaviour under short-circuit conditions. Immediately a short-circuit is applied, the increased armature reaction reduces the main flux which links with the exciter winding and the high-tension windings. This results in a rapid fall in excitation, and in generated high-tension voltage the generators will continue to run on short-circuit with fair commutation.

This characteristic is valuable, because in all treaters occasional spark-over occurs between the electrodes, due to the accumulation of deposit at local points or to changes in gas conditions. Under such conditions the generators are subjected to a sudden dead short-circuit, and the behaviour of the unit in this event is one of its outstanding advantages. The generators withstand repeated short-circuit without damage; on each occasion the voltage falls rapidly until the arc is extinguished. The voltage then automatically builds up again and remains normal until a further spark-over occurs.

The control gear is of the simplest possible form. At the low-tension end there are the usual isolating switches, a motor starter with low-volt and time lag overload protection, and a motor speed regulator which serves to control the generated voltage. With direct-current drive speed regulation is by motor field control. With a 3-phase alternating current supply the drive is by slipring induction motor, and speed variation is effected by the variation of rotor resistance.

In the earth lead from the generator is connected a milli-ammeter measuring the treater current, and a time lag current overload relay.

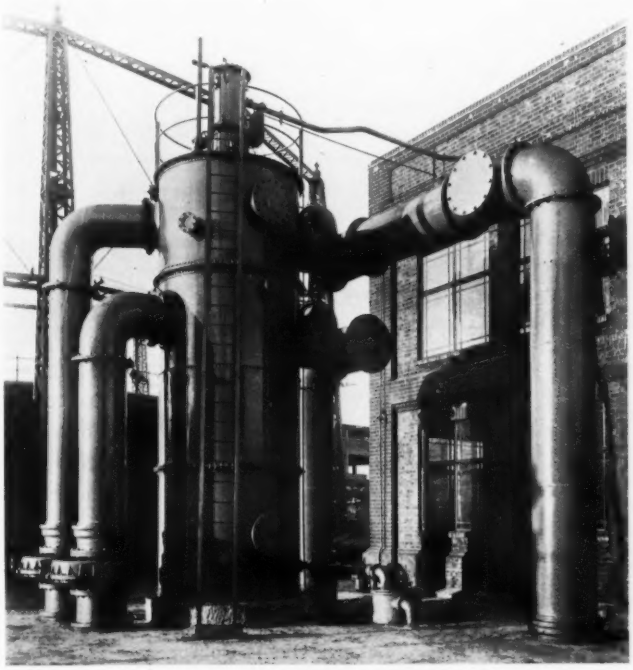


Fig. 3. Plant for the Electrical Precipitation of Tar Fog installed at the Tottenham and District Gas Co's. works.

In the event of a sustained short-circuit, due, for instance, to the breakage of a wire in the treater, this overload relay shuts down the set by tripping the motor low-volt release. Distant visual and aural signals are provided to indicate the shut down of the set.

These equipments are run continuously day and night, except for periodic shut downs of about one hour for cleaning. The interval at which this is advisable varies from one week to one month, depending on local conditions.

One detarring plant has been in use by the Nunnery Gas & Coke Oven Company, of Sheffield, for eighteen months, cleaning coke-oven gas. The high-tension generating plant is housed near the exhauster plant and the coke ovens. Though the atmosphere is such that bright copper turns blue in a few hours, no ill effects have resulted. This plant is cleaned every fortnight.

Figs. 3 and 4 show the plant supplied to the Tottenham & District Gas Co. for extracting tar from water gas or alternatively from coal gas. The treater was manufactured by the Whessoe Foundry & Engineering Co., Darlington, and the electrical equipment by the English Electric Co. The capacity of the plant is 6 million cubic feet per day.

Two interesting orders recently received, in conjunction with the Whessoe Foundry Co., are a Detarring Plant for the Perth Gas Works, Australia (per William Coward), and for a Blast Furnace Gas Cleaning Plant for Messrs. David Colville, Glasgow, for a treater to clean 5 million cubic feet of blast furnace gas per hour. The English Electric Company are supplying four 40-kV. generating sets and all the necessary switchgear.

By the courtesy of Mr. J. Bradwell, Manager of the Nunnery Gas & Coke Oven Company, Sheffield, we are permitted to give the following extracts from his recent paper to the Midland Section of the Coke Oven Managers' Association. The data given shows the very great gain resulting from the electro detarrer. The plant to which the data refers is operated by the Nunnery Gas & Coke Oven Company. The electro detarrer was supplied by the Whessoe Foundry & Engineering Company, and incorporates "English Electric" high-tension direct-current generators.

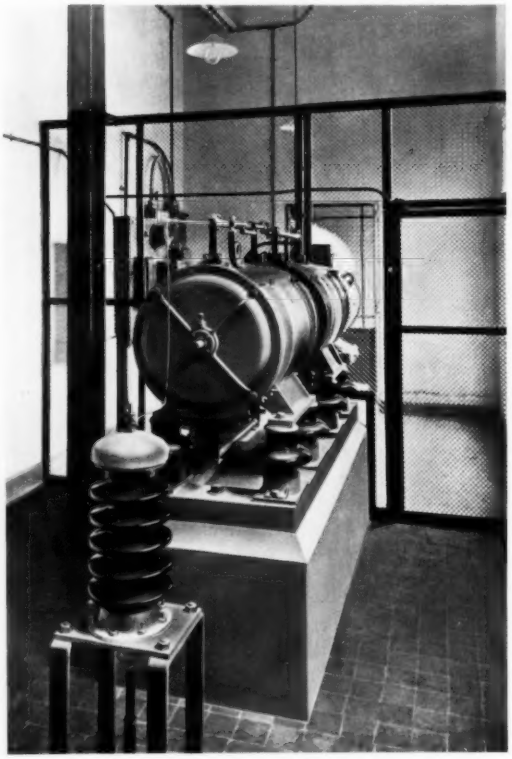


Fig. 4. End view of Generators, showing connection to H.T. Cable leading to the Treater illustrated in Fig. 3.

Operating Data of the W.W-D Electro Detarrer

The precipitation efficiency is illustrated by the following typical results, which were obtained at an electrode voltage of 26,000.

TABLE I.

The Efficiency of Electrical Precipitation.

Test No.	1	2	3	4	5	6
Wet tar precipitated, lb./hr.	123.4	116.4	107.0	161.6	92.0	117.2
Water content, per cent.	35	44	61	39	35	50
Dry tar precipitated, lb./hr.	80.2	65.2	41.7	98.6	59.9	58.6
N.T.P. gas throughput, th. c. ft./hr.	290	280	268	290	283	275
Inlet dry tar fog, grains/100 c. ft.	194	163	109	239	149	149
Outlet dry tar fog, grains/100 c. ft.	0.65	0.80	0.93	1.20	1.00	1.00
Precipitation efficiency, per cent.	99.7	99.5	99.2	99.5	99.3	99.3
Actual velocity of gas through the treator, ft./sec.	4.4	4.2	4.0	4.4	4.2	4.2
Temperature of gas treated, deg. F.	80	79	79	86	82	82

Referring to Table II, it will be realised that in view of seven million cubic feet of gas being circulated daily, heavy depositions of tar fog in the by-product units, particularly the ammonia saturators, occurred. Cleaning of the ammonia saturators, which are of totally enclosed pattern, was enforced at intervals of six weeks. By resorting to the use of a sealed overflow, it was possible to remove tar continuously from the saturator and extend the period between cleanings, but this involved additional apparatus in the form of suitable storage accommodation for the acid liquor, heating coils and lifters.

TABLE II.

Tar Fog Retained by the Gas Throughout the By-product Plant Cycle, Before Electro-Detarring.

	Grains/100 c.ft.	Lb./million c.ft.
Outlet of P. & A. extractor	10	14.3
Inlet of benzole scrubbers	2.5	3.6
Outlet of benzole scrubbers	1.2	1.7
Inlet of compressor ...	0.6	0.86
Outlet of compressor ...	0.004	0.006

Return pipes from the acid catch box to the saturator were frequently obstructed, resulting in entrainment of acid with the gas and corrosion of the subsequent gas range. The saturator valves quickly became immovable unless frequently operated. Tar adhered to the sulphate crystals, and not only impaired their colour, but rendered drying more difficult.

Sludging of gas oil used for benzole absorption was accelerated by the presence of tar fog and resulted in heavy depositions on the scrubber grids, in heat exchangers, oil coolers and oil storages. Steaming of the scrubbers gave relief for a time, but this became less and less effective, until the procedure became a monthly feature and eventually removal of the grids for cleaning was enforced.

Table II shows that about 50 per cent. of the tar fog escaped the baffling effect of the scrubbers and passed forward with the gas, a feature which denotes the finely divided state of the fog.

In the water-sealed gasholder, the tar fog at reduced pressure apparently acted as nuclei for the formation of bulky emulsified material, which was ultimately deposited in the succeeding gas mains and compressors. Cleaning of the gas ranges was necessary, regardless of adequate drip-pots, after the passage of approximately every 90 million cubic feet of gas, which, in the case of the surplus gas range, amounted to intervals of three to four weeks.

It was necessary to dismantle the gas compressor about every four weeks for removal of deposit from the piston heads and valves, the latter, on account of their small lift, acting as excellent gas filters. Expenditure and loss of revenue, amounting to £400 per annum, was incurred in contending with these difficulties, and the risk of considerable breakdown expense in the case of damage to the gas compressors or saturator leadwork was always present. The installing of the W.W-D detarrer has entirely eliminated all these troubles. Saturator operations are markedly improved and the service of these units is restricted only by the infrequent attention to the lifters. Sulphate of ammonia is of well-defined crystals, easily dried and white in colour. The gas oil at the benzole plant is clean and free from emulsions, a circumstance which has obviated the necessity for frequently cleaning the preheaters, heat exchangers, oil coolers, etc.

Since the installing of the detarrer, the resistance offered by the scrubbers has remained quite stationary, indicating the absence of any material being deposited on the grids. Cleaning of the gas mains and compressors is now unnecessary, the compressors give continuous and efficient service, and on routine examination after six months' use show no depositions on the valves or piston heads.

The foregoing clearly indicates the advantages gained by the installation of the W.W-D detarrer and the following comparison shows the financial saving effected yearly :—

PELOUZE AND ANDOUIN EXTRACTOR.

	£	s.	d.
Capital cost, including valves and connections	650	0	0
Interest and depreciation at 12½ per cent. ...	81	0	0
Power to overcome 10 in. W.G., say 12 B.H.P. 30 lb. steam/B.H.P. = 360 lb./steam/hour at 1s. 6d. ton	87	0	0
Maintenance and supervision ... say	10	0	0
Expenditure and loss of revenue due to inefficient tar extraction...	400	0	0
	£578	0	0

W.W-D DETARRER.

	£	s.	d.
Capital cost, including valves and connections	1,500	0	0
Interest and depreciation at 12½ per cent. ...	187	10	0
Power, 2.9 kW. at ½d.	53	0	0
Maintenance and supervision ... say	10	0	0
	£250	10	0

Official Opening of Copenhagen Suburban Electric Service on the Danish State Railways.

Trial running of the electric service between Vanlose and Hellerup commenced on the 29th November last, and on 3rd April this year the official opening ceremony inaugurating the public service was performed.

A six-coach train was run from Frederiksberg Station to Klampenborg carrying the Danish Minister of Transport, the General Manager of the Danish State Railways, and about 200 guests. On arrival at Klampenborg a short ceremony was held, at which the general outline of the electrification scheme was described. This scheme comprises the ultimate electrification of all suburban lines within a radius of about 20 kilometres of Copenhagen. The trains were then formally accepted by the Railway.

Following the opening ceremony, which took place at 2 p.m., a regular public service was commenced at 4.13 p.m., and has continued without any hitch or trouble. The Danish State Railway Authorities are to be congratulated on the thoroughness with which they have prepared and carried out this scheme, and the success which has attended this electrification through all its stages up to date has done a great deal to enhance the prestige of British electrical engineering on the Continent.

The English Electric Company received the order for the whole of the electrical equipment of the rolling stock.

The equipment embodies the latest features of electric traction practice. The motors are self-ventilated, but draw air through ducts in the coach body to minimise the possibility of brake-block dust and other dirt getting into the motor interior. The control gear of the all-electric camshaft type is carried in cases on the coach underframe, and the case covers are interlocked with main H.T. switches and the pantograph control, so that all equipment is

Scene at the official opening of the Copenhagen Suburban Electric Service.

automatically made "dead" before the cases can be opened. Automatic acceleration is provided and the acceleration rate can be adjusted by the driver by means of a push button control to meet varied conditions of rail, particularly when snow or ice is present.

At present the electric service is being maintained to a 20-minute schedule on the line from Frederiksberg to Vanlose and Klampenborg. Reports of the first week's working show that the number of passengers carried on the first Sunday of regular electric working showed an increase of 140 per cent. over the normal for this time of the year.

All indications point to the prospect that the result of this electrification will be to build up a very much greater volume of suburban traffic from Copenhagen in the same way that the electrification of the Southern Railway has built up similar traffic in England.

57 RAILWAYS IN 18 COUNTRIES
HAVE ADOPTED
'ENGLISH ELECTRIC' TRACTION EQUIPMENTS

GT. BRITAIN	6	DENMARK	1	JAPAN	26	POLAND	1
ARGENTINA	1	FRANCE	3	MOROCCO	1	S. AFRICA	1
AUSTRALIA	1	HOLLAND	1	NEW ZEALAND	2	SPAIN	2
BRAZIL	1	INDIA	3	PERU	1	URUGUAY	1
CANADA	3					VENEZUELA	2

Complete Railway Electrification Schemes Undertaken in any part of the World

"MARELLI"

(Regd. Trade Mark)

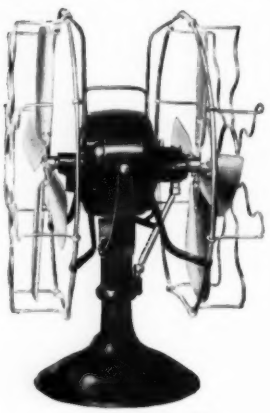
ELECTRIC FANS

NEW DR-14 "SANDI" TYPE

DOUBLE BLADED FAN.

Fitted with 4-speed Regulator.

Rotates through a complete circle 8 times per minute (i.e., 16 impulses of air per minute).



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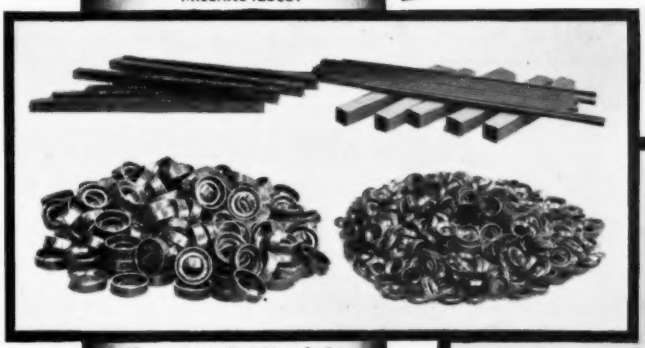

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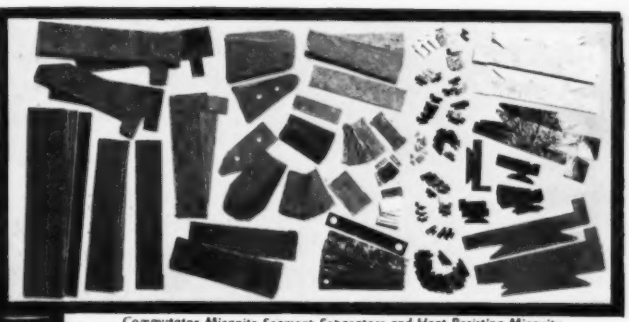

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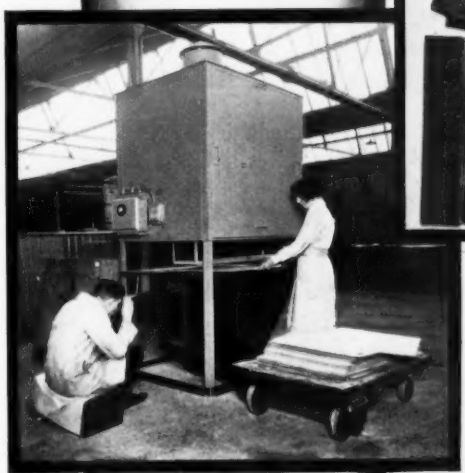

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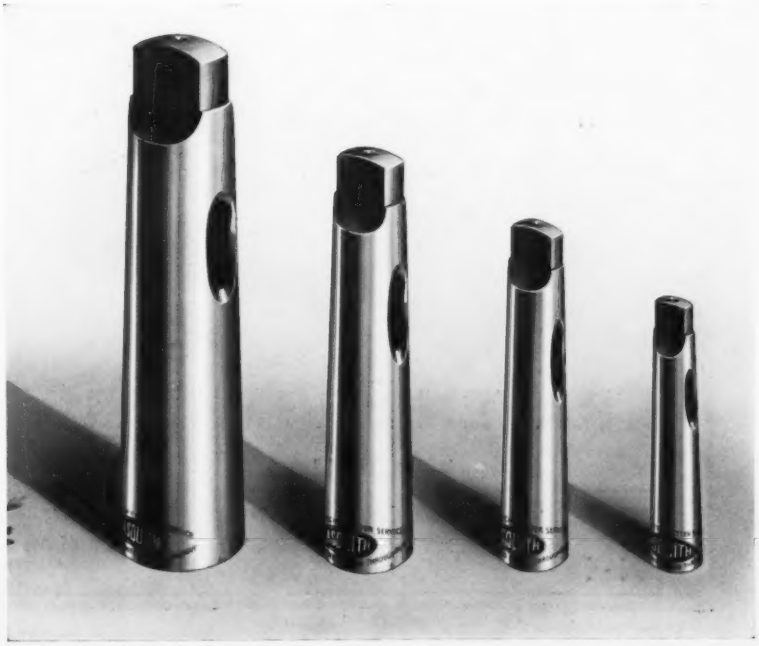

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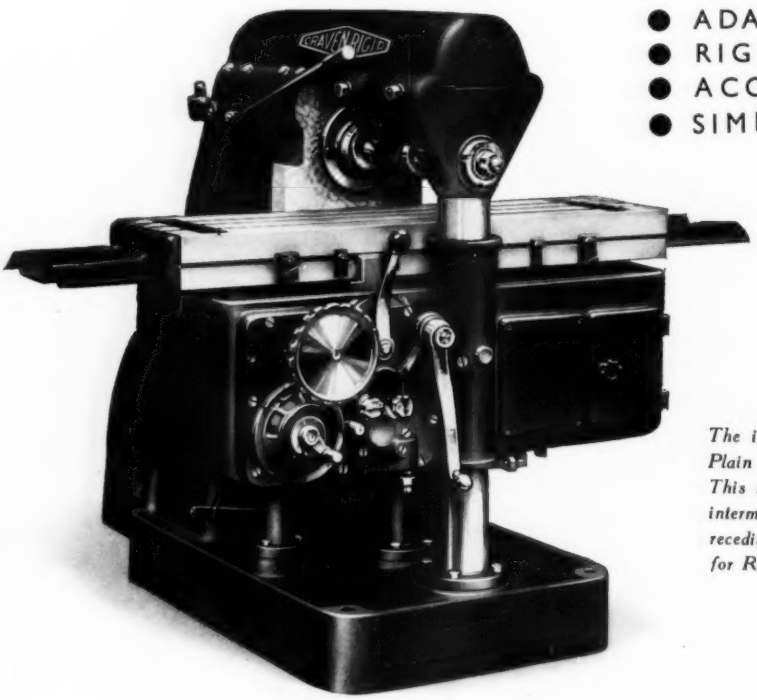

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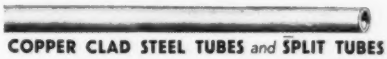

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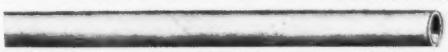

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